



Today's Webinar Moderator  
 Betsy Rakola  
 Organic Policy Advisor  
 US Department of Agriculture  
 Agricultural Marketing Service

# USDA Natural Resources Conservation Service Science and Technology

## 2015 Conservation Webinars



Today's Webinar Presenter  
 Erin Silva, Ph.D., Assistant Professor,  
 Organic and Sustainable Cropping Systems  
 Specialist, University of Wisconsin-  
 Madison, Madison, WI

Date	2015 Conservation Webinars Topics
May 21	Environmental Benefits of Organic Agriculture: Energy and Climate Change
June 17	Environmental Benefits of Organic Agriculture: Biodiversity
August 27	Environmental Benefits of Organic Agriculture: Soil
Sept 23	Environmental Benefits of Organic Agriculture: Water Quality



On-demand replays are available within a couple of days of the live webinar.

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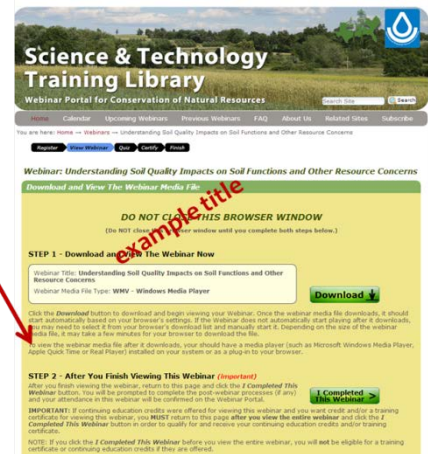
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United States Department of Agriculture

# The Environmental Benefits of Organic Agriculture



Part 1: Climate Change & Energy

# Impacts and Implications for Organic Agriculture in a Changing Climate



Erin Silva

Assistant Professor

Organic Cropping Systems

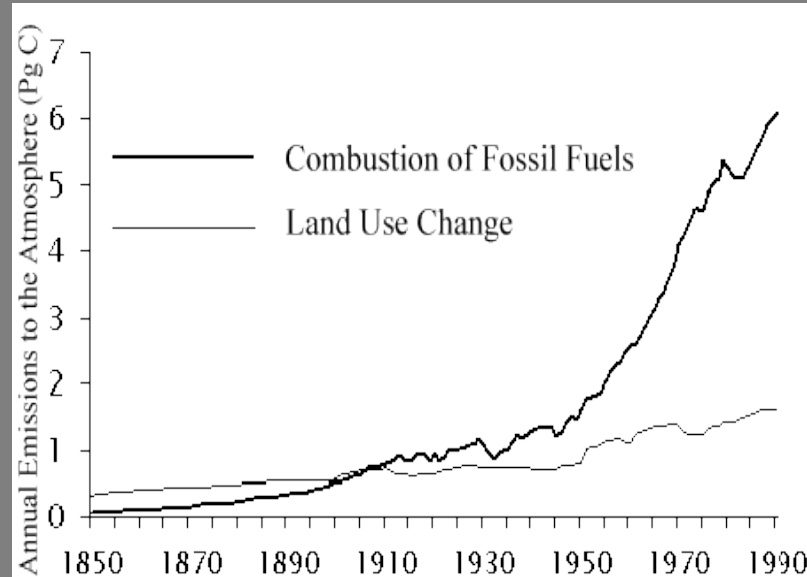
Univ. of WI Dept. of Plant Pathology

# Outline of Presentation

- Climate change and agriculture
- Impact of organic agriculture on emissions: carbon sequestration and nitrous oxide emissions
- Potential improvements and mitigation strategies and relationship to organic agriculture

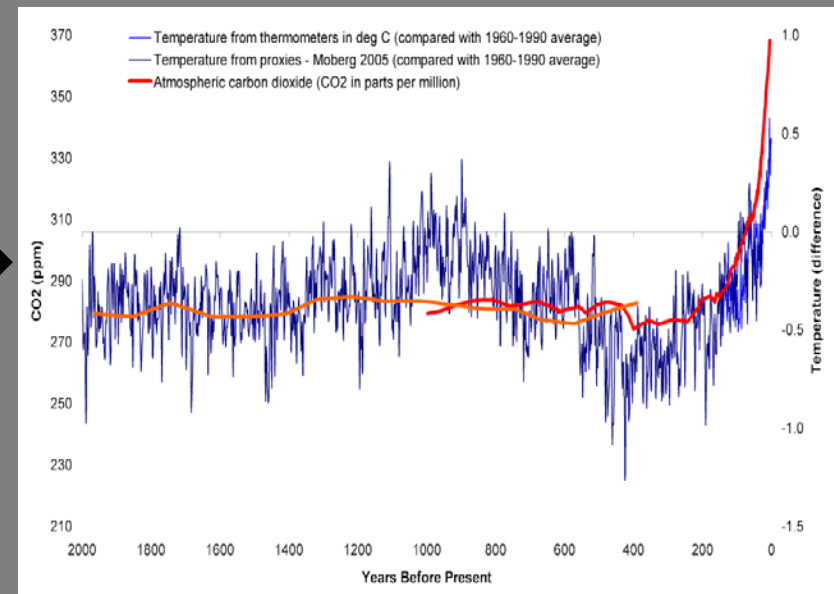
# Agriculture & the climate

## Source of C emissions



<http://www.prism.gatech.edu/>

## CO<sub>2</sub> & climate change



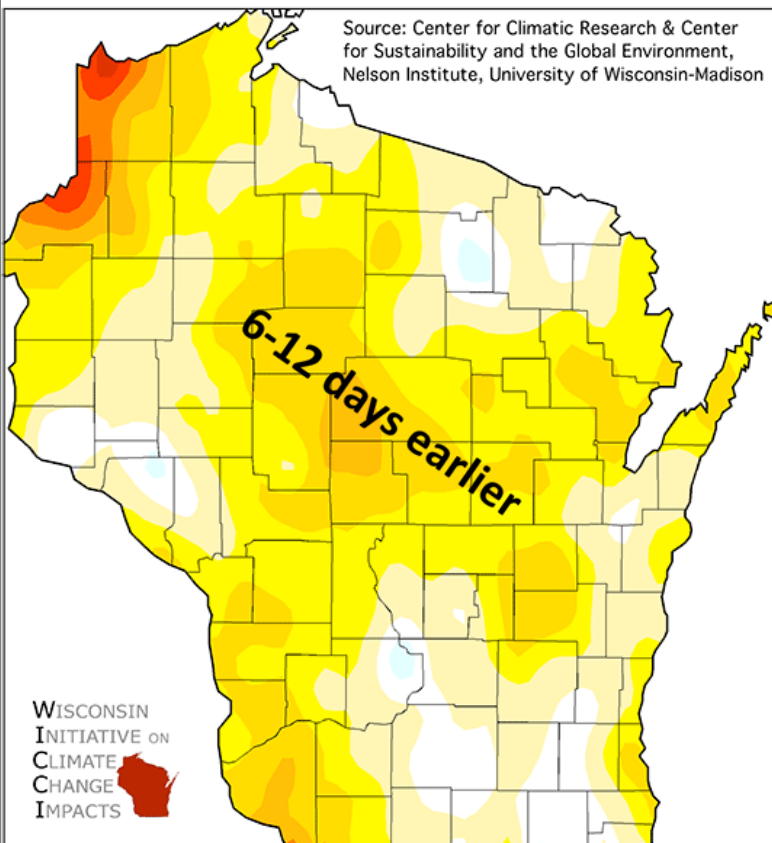
*Moberg et al. 2005*

- Change in temperature & rainfall
- Extreme weather: drought, flood, storms
- ***Food & resource insecurity***

# Dates of Spring and Fall Freeze

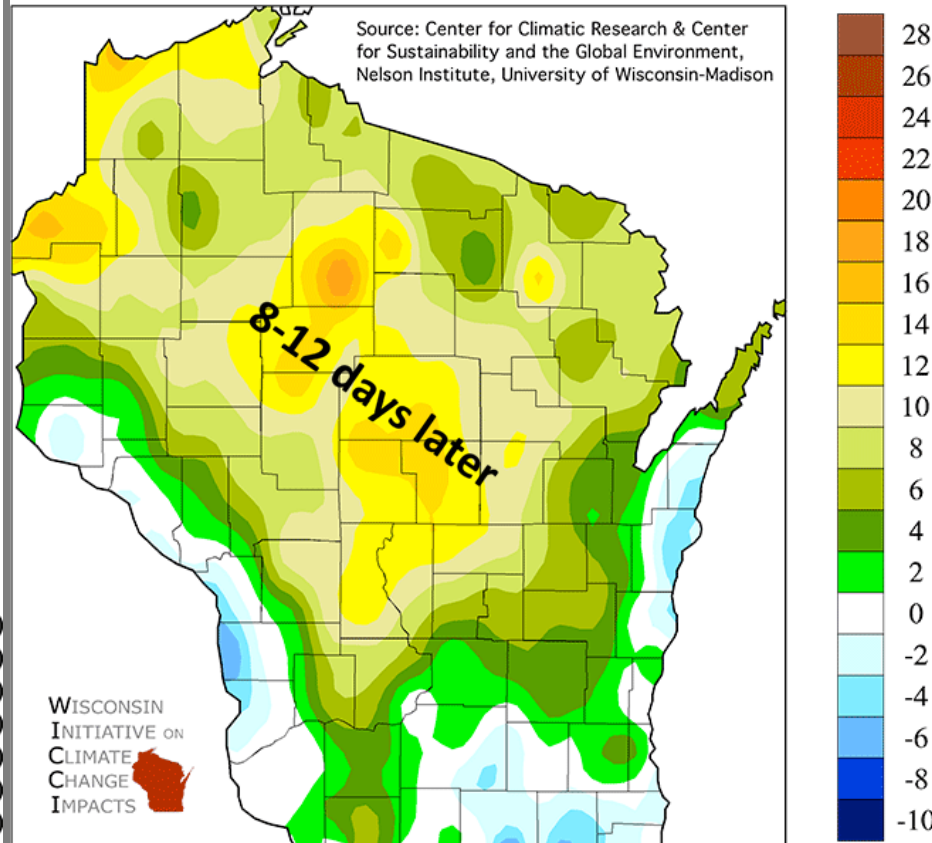
Change in Average Date of Last Spring Freeze from 1950 to 2006

Source: Center for Climatic Research & Center for Sustainability and the Global Environment, Nelson Institute, University of Wisconsin-Madison



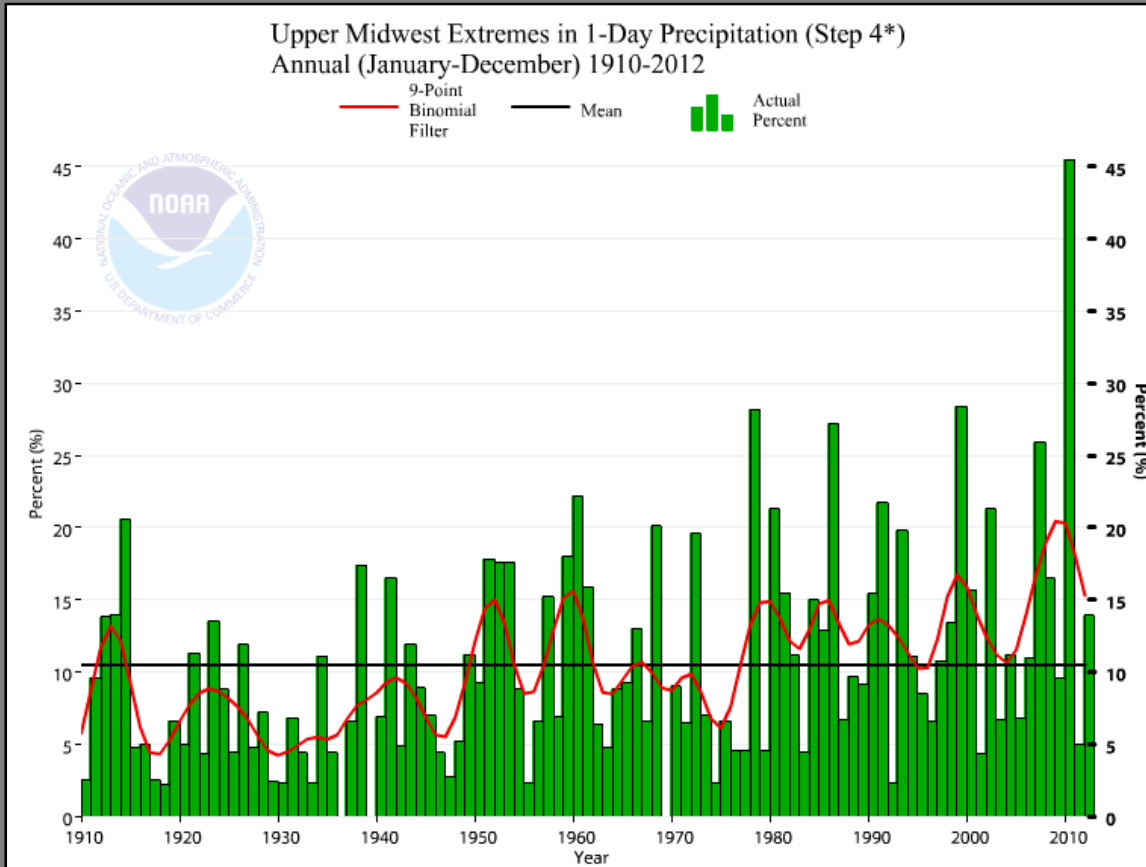
Change in Average Date of First Autumn Freeze from 1950 to 2006

Source: Center for Climatic Research & Center for Sustainability and the Global Environment, Nelson Institute, University of Wisconsin-Madison



Wisconsin growing season  
lengthened by 1-4 weeks since 1950

# Upper Midwest Precipitation Trends 1910 - 2012

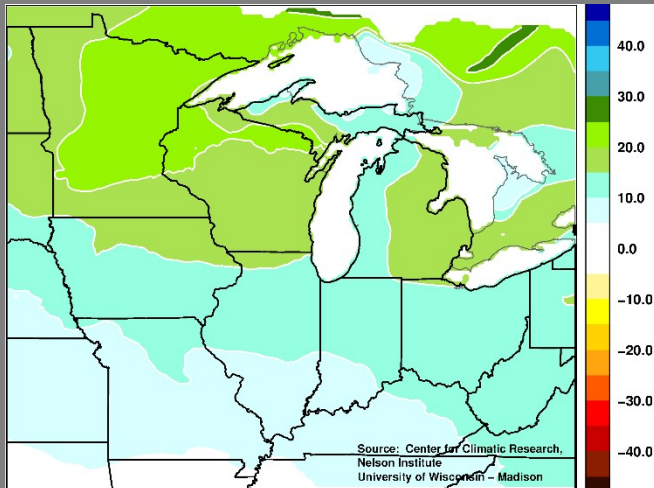


8 of 10 of the wettest years for daily *precipitation* have occurred since 1978

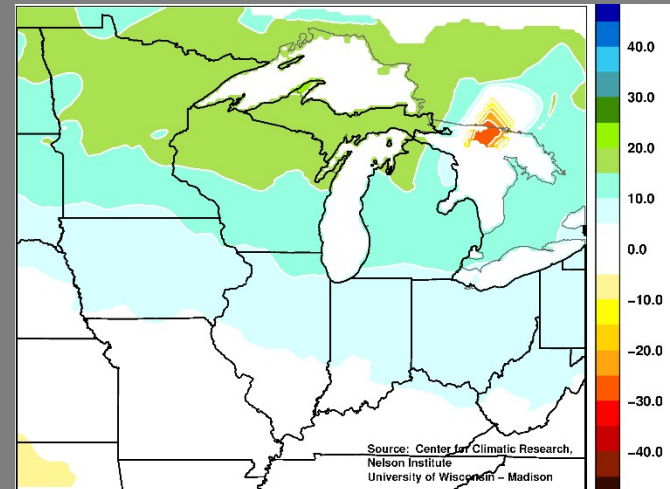
# Seasonal change in precipitation

## 1980-2055 (SRES A1B)

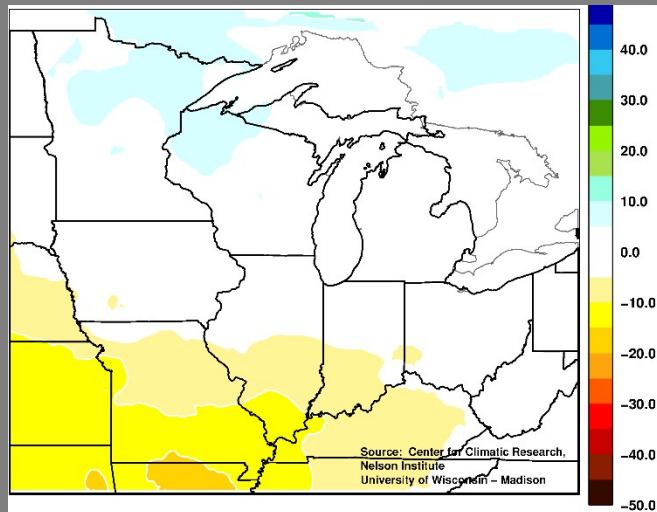
### Winter +20-25%



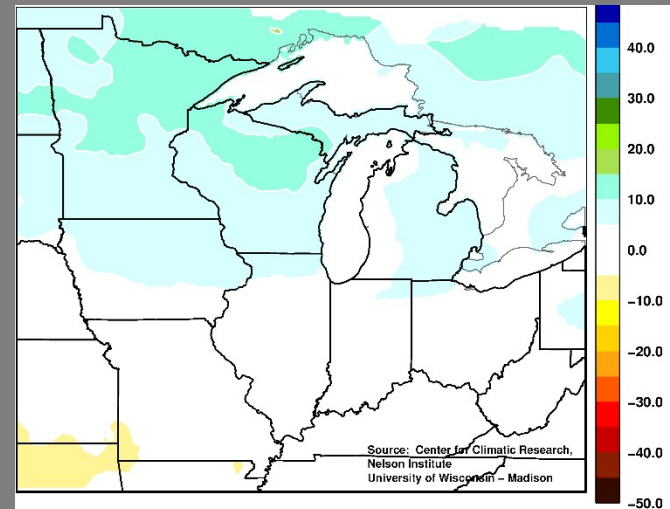
### Spring +10-20%



### Summer +0-5%



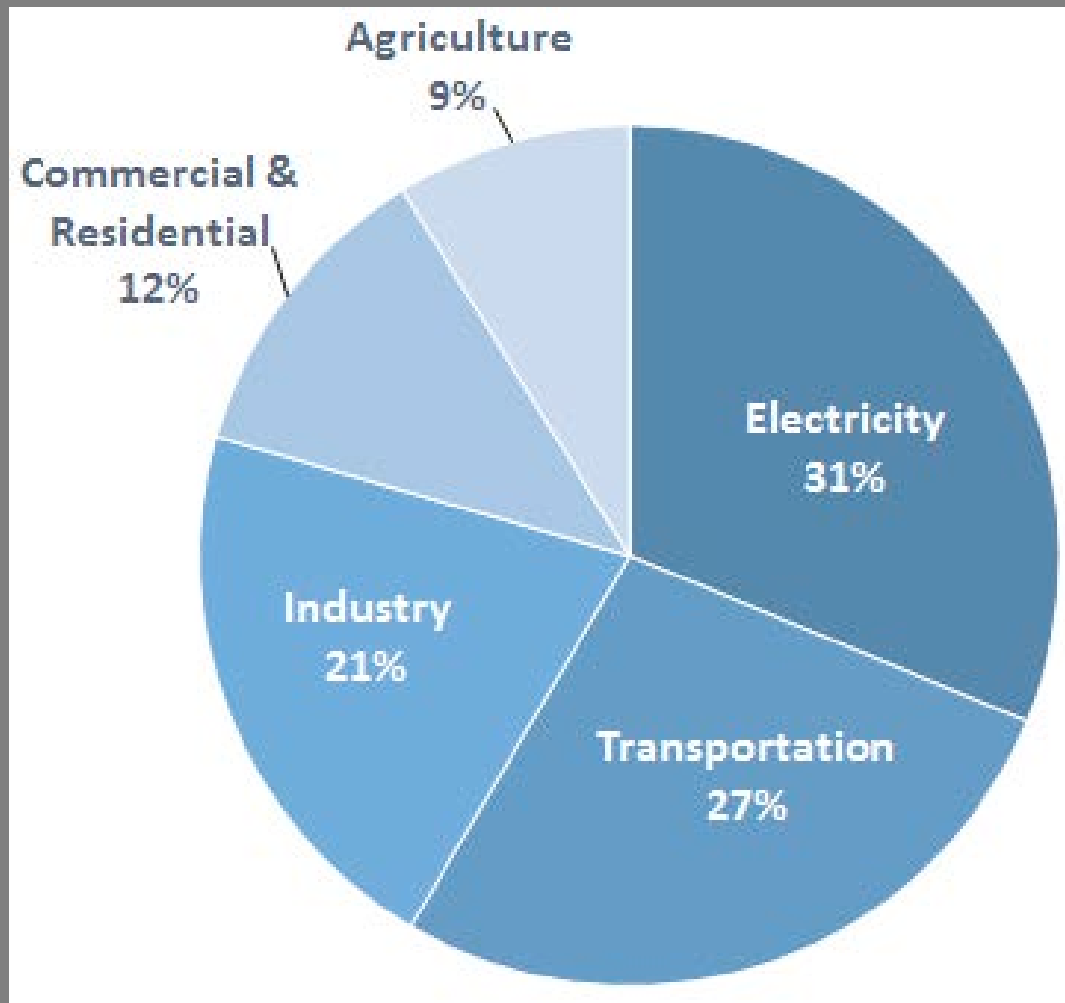
### Fall +5-10%



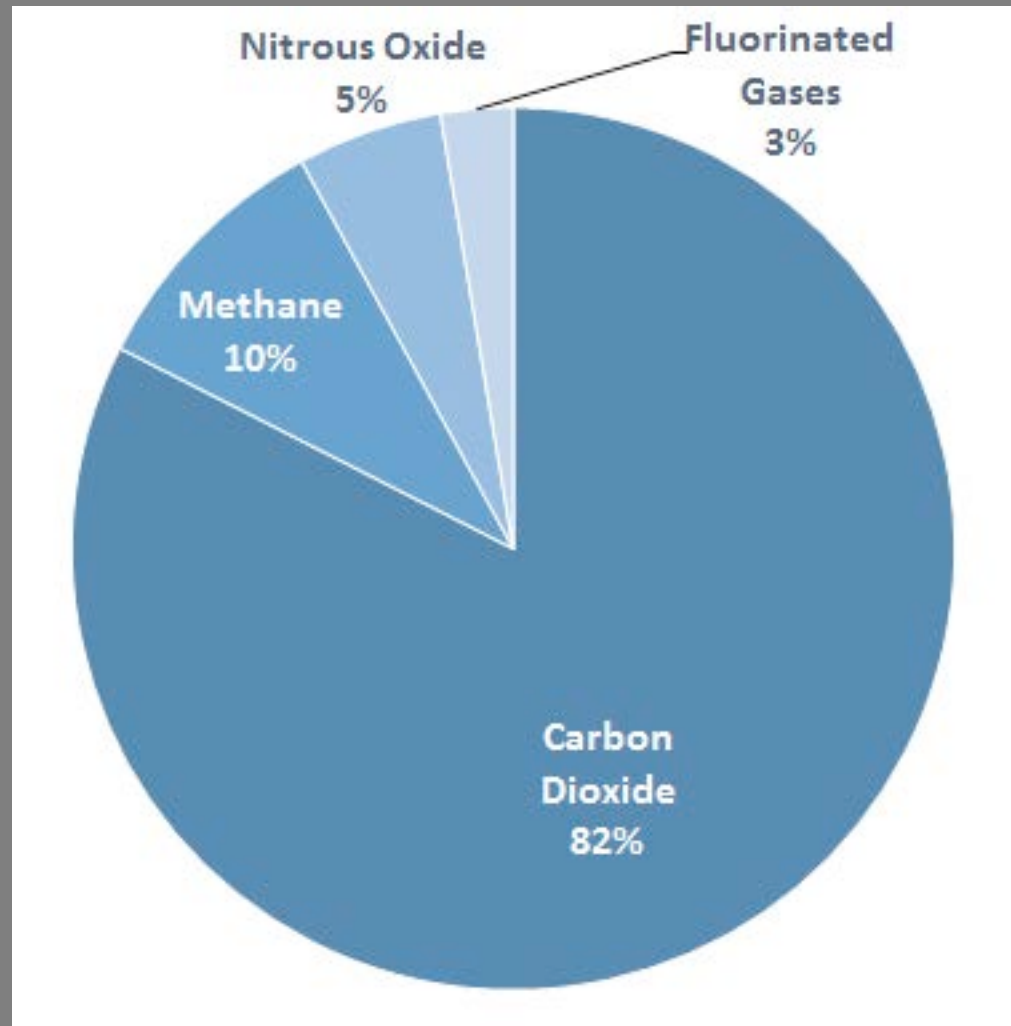
# What is the cause of this change?



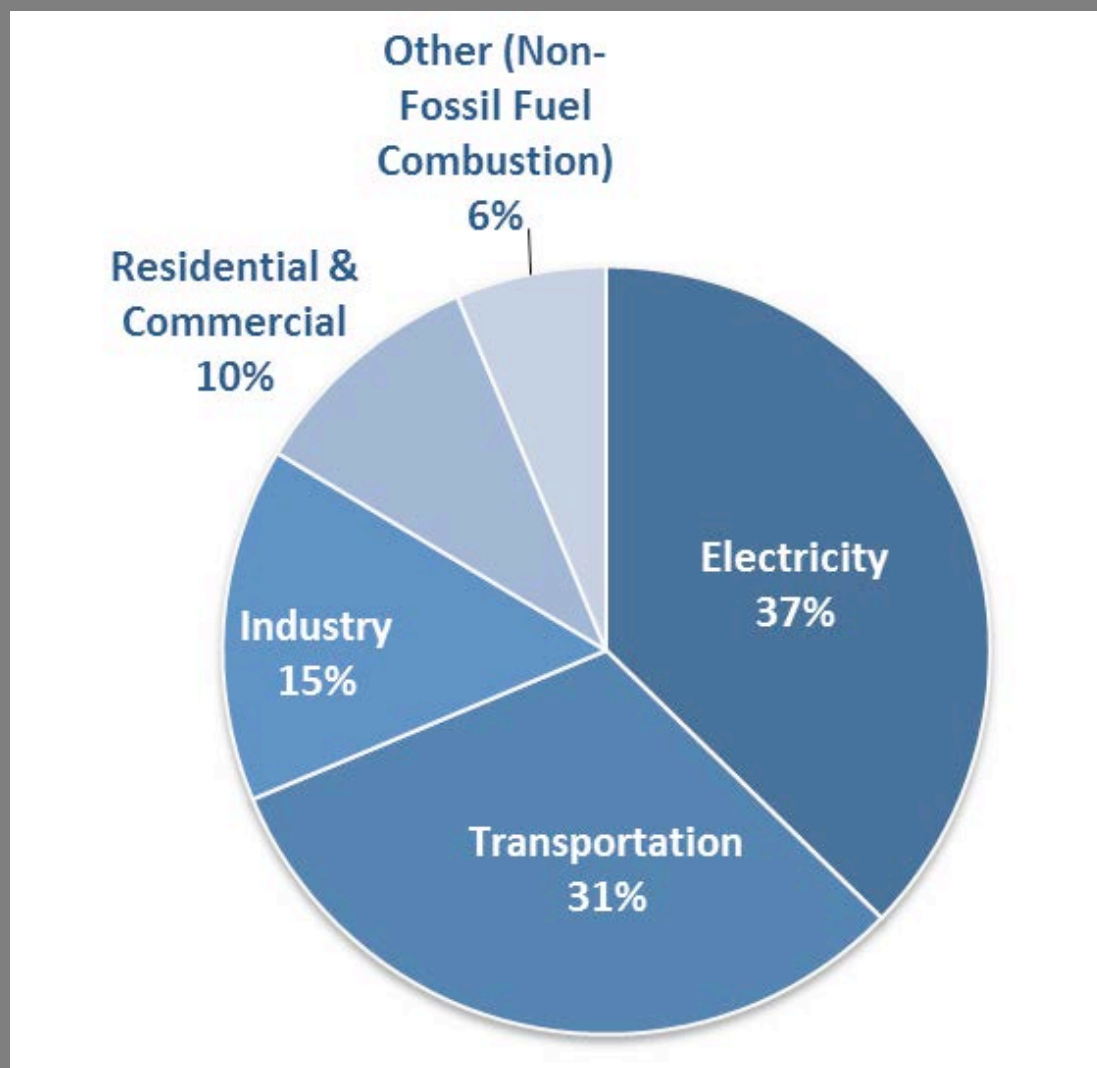
# Total U.S. Greenhouse Gas Emissions by Economic Sector in 2013



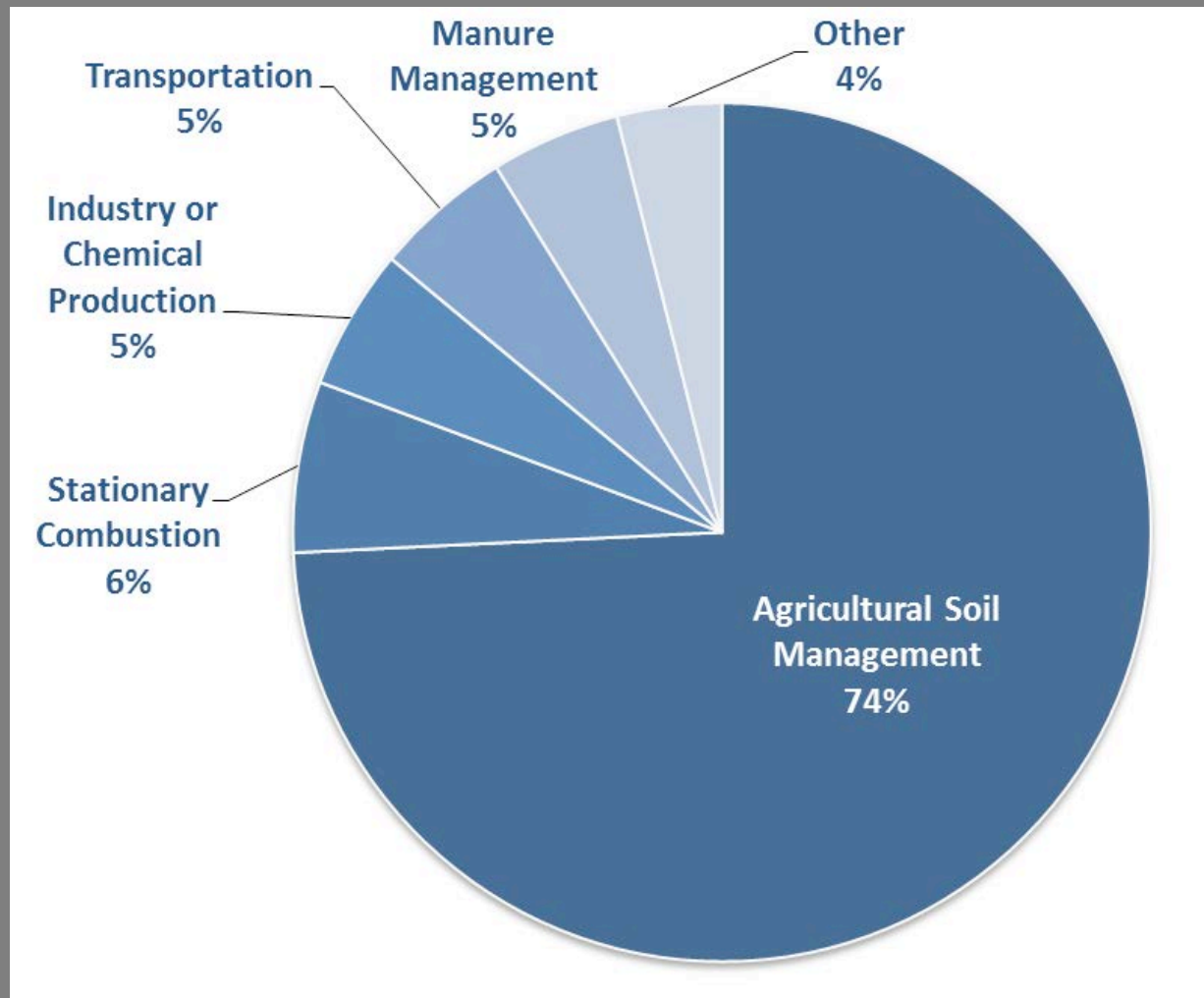
# U.S. Greenhouse Gas Emissions in 2013



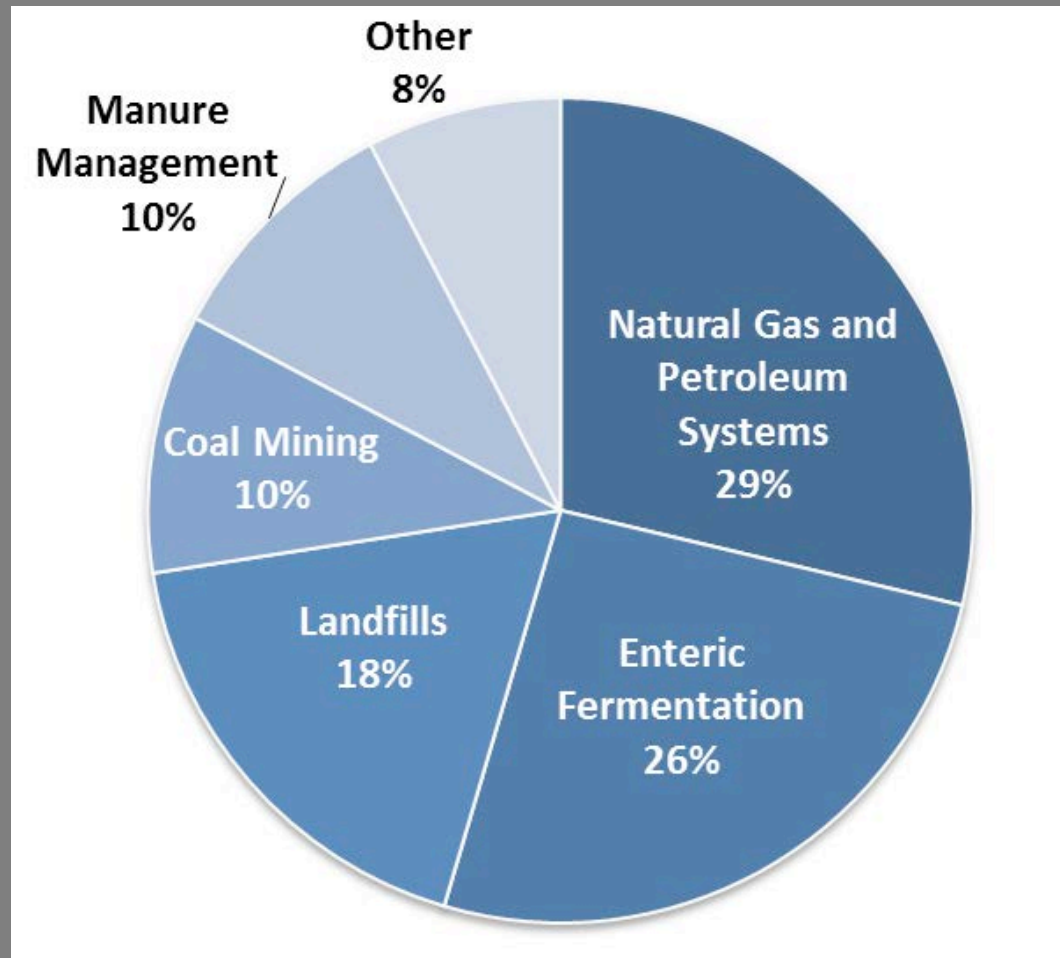
# U.S. Carbon Dioxide Emissions



# U.S. Nitrous Oxide Emissions (6% overall GHG emissions)



# U.S. Methane Emissions (9% overall GHG emissions)

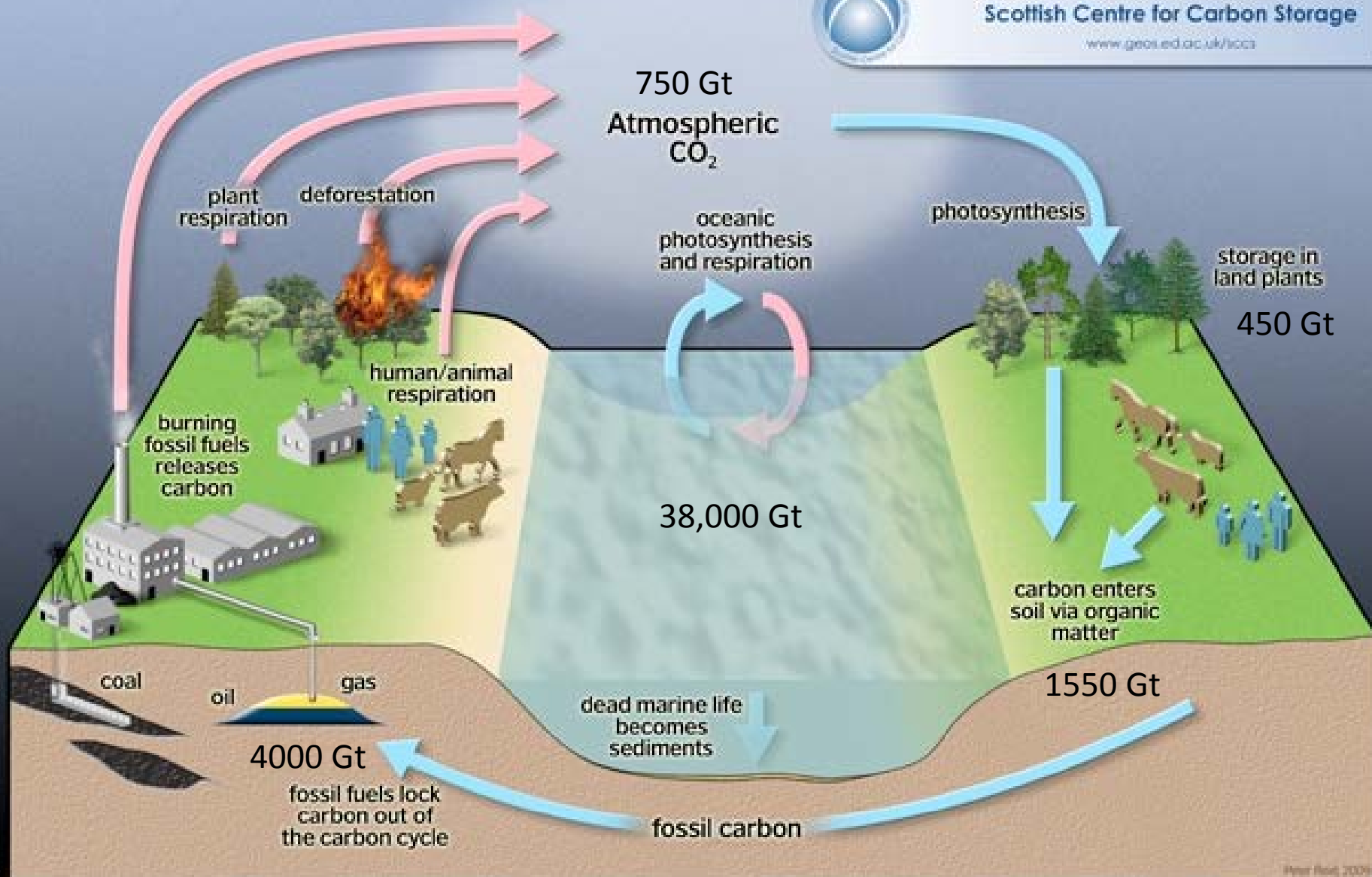


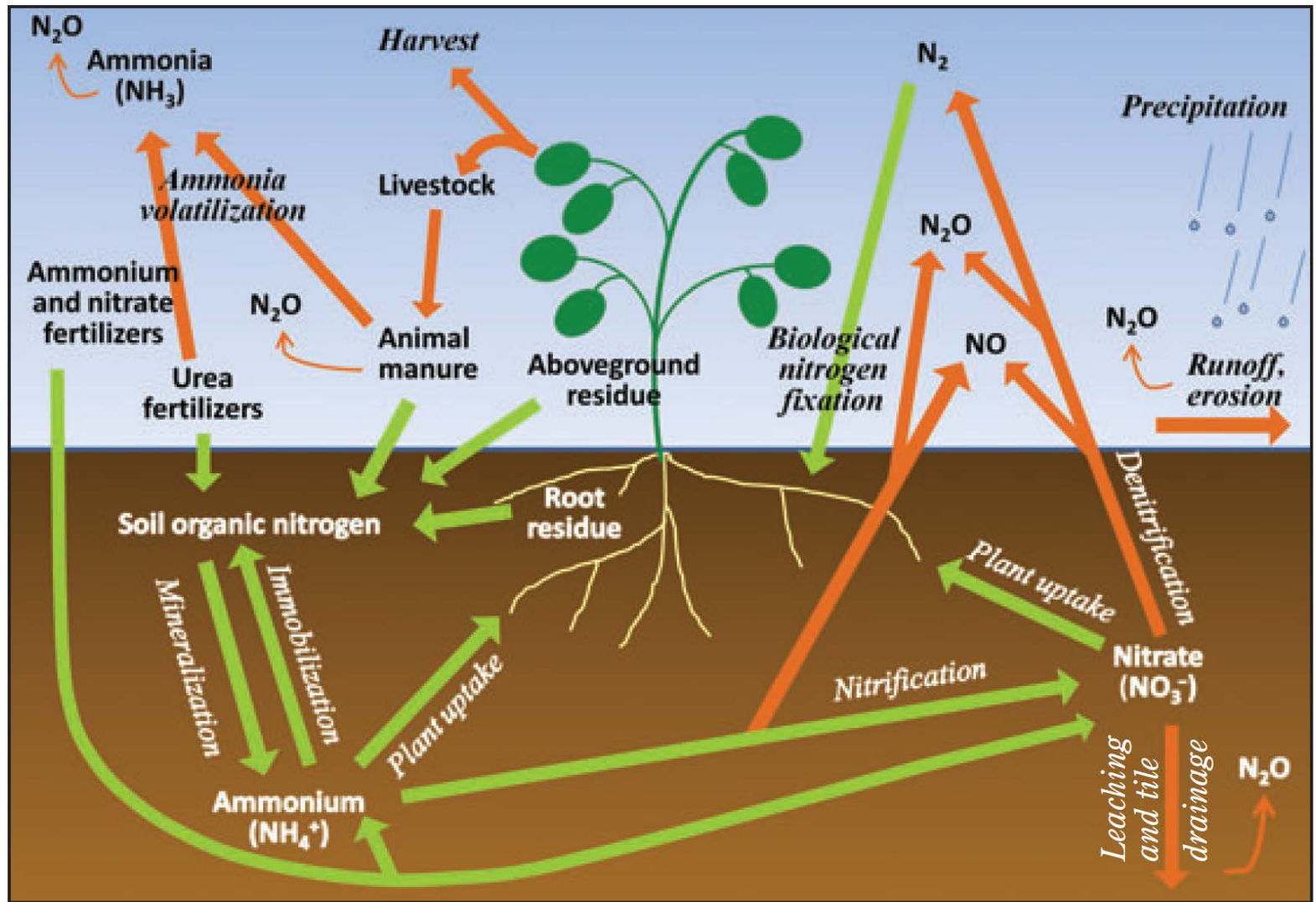
<b>Selected Greenhouse Gases</b>				
<b>Gas</b>	<b>Atmospheric Concentration</b>		<b>Atmospheric lifetime (Years)</b>	<b>100 Year Global Warming Potential (GWP)</b>
	<b>Pre-industrial (1000-1750)</b>	<b>Recent (1998)</b>		
<b>Carbon dioxide (CO<sub>2</sub>)</b>	280 ppm	365 ppm	50-200	1
<b>Methane (CH<sub>4</sub>)</b>	0.7 ppm	1.745 ppm	12	23
<b>Nitrous oxide (N<sub>2</sub>O)</b>	0.270 ppm	0.314 ppm	114	296
<b>Perfluoromethane (CF<sub>4</sub>)</b>	40 ppt	80 ppt	>50,000	5700
<b>Sulfur hexafluoride (SF<sub>6</sub>)</b>	0	4.2 ppt	3200	22,200

ppm = parts per million  
ppt = parts per trillion

Source: U.S. Environmental Protection Agency website  
Energy Information Agency (DOE): Emissions of Greenhouse Gases in the United States 2004, December 2005

GWP = relative measure of how much heat a greenhouse gas traps in the atmosphere<sup>15</sup>





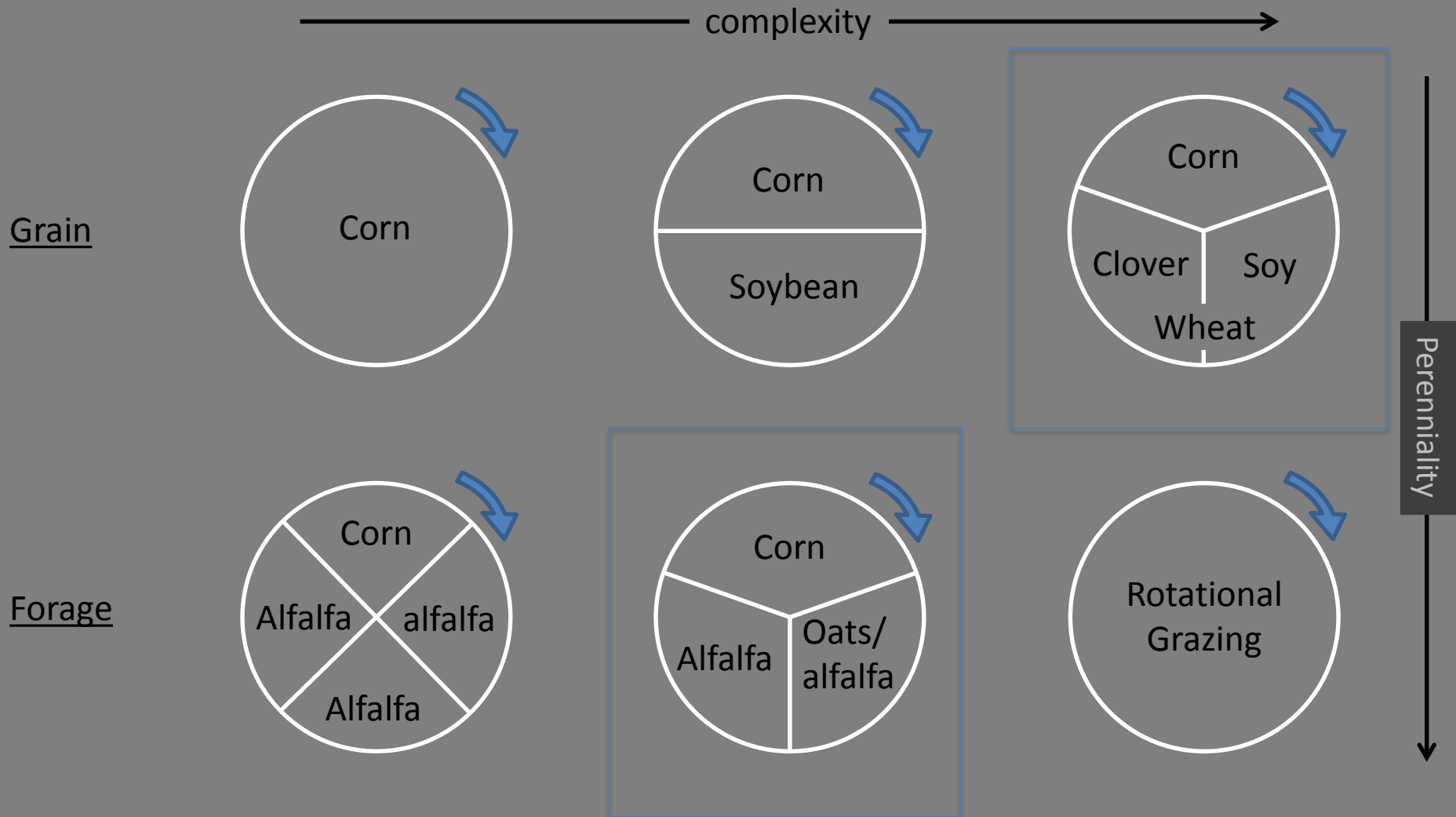
**Figure 1.** Schematic diagram of the nitrogen (N) cycle showing N forms (upright font) and transformations (italics). Nitrogen inputs are shown as

# The Wisconsin Integrated Cropping Systems Trial

Arlington, WI



# WICST Cropping Systems



# Comparing the Emissions of these Cropping Systems (LCIA)

- Where are the boundaries?
  - Embedded emissions
  - In-field emissions



Wikimedia Commons: James T M Towill

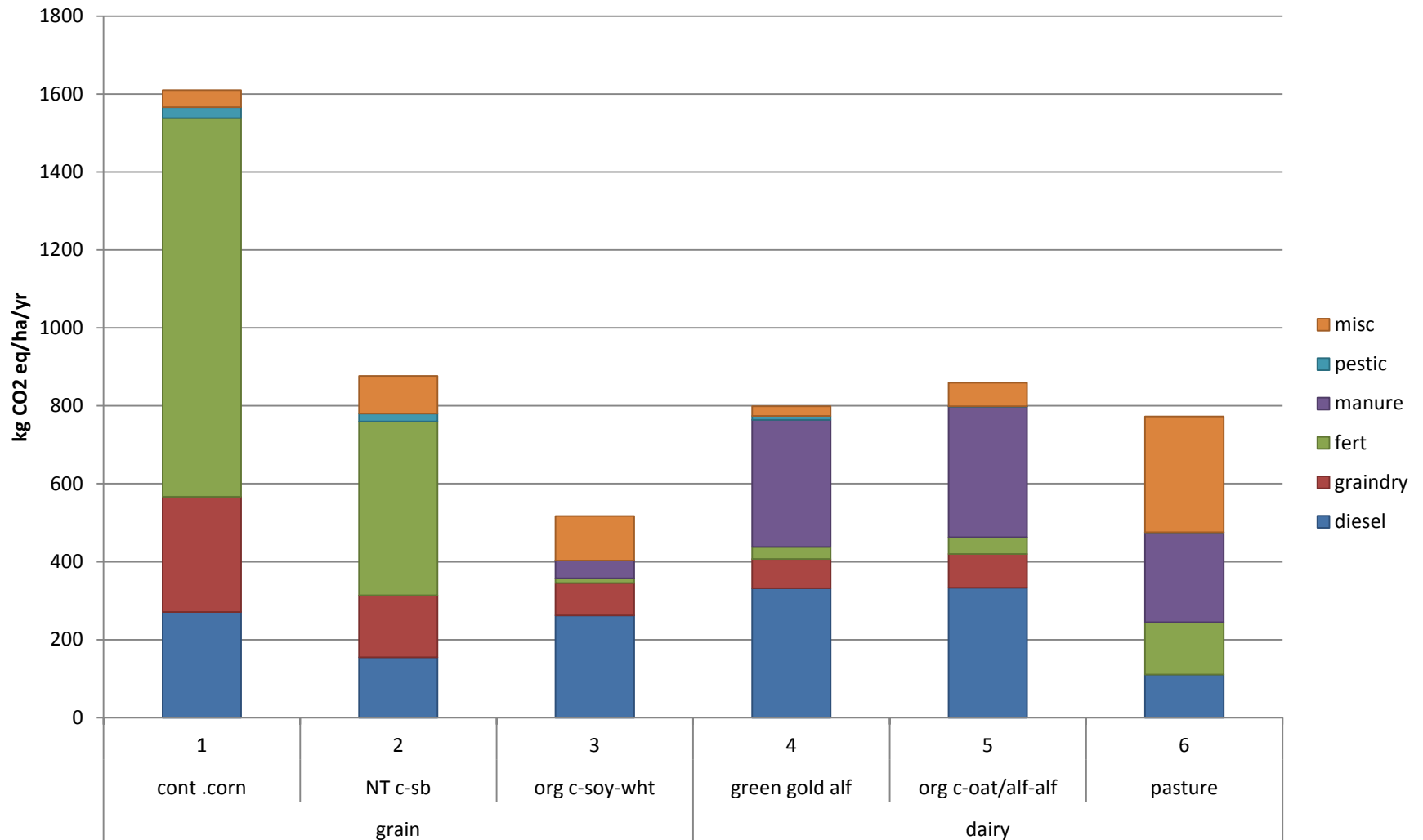


<http://www.afrifertilizers.com/prices.html>

# WICST Life Cycle Impact Assessment

- Embedded emissions: accumulated emissions emitted over the entire production process
- Data from the GaBi databases
  - Seed
  - Diesel
  - Fertilizer
  - Pesticides
  - Grain drying
  - Supplemental heifer feed while on pasture

# Embedded components at ARL (kg CO<sub>2</sub> eq/ha/yr), 1993-2008



# Carbon Sequestration



# Agriculture & the global C budget

## CO<sub>2</sub> mitigation via agriculture

- Agricultural land as a C sink
- Reverse historic losses of SOC

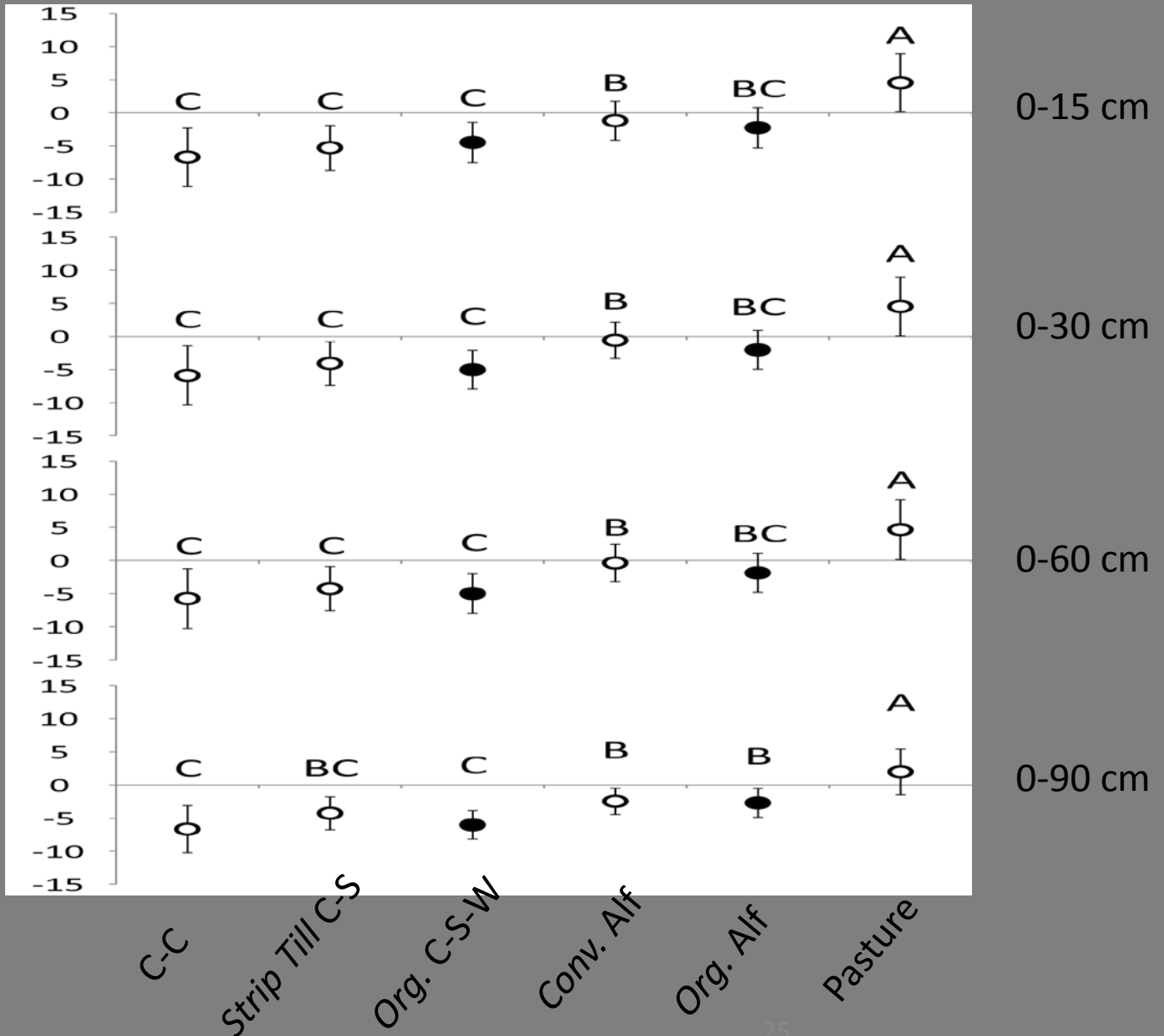
## Attractive mitigation option

- Immediately implementable
- Cost-effective



# WICST SOC trends

Change in Soil Carbon Over 20 years ( $\text{Mg ha}^{-1}$ )



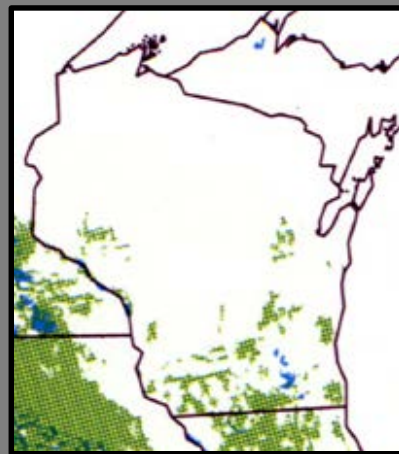
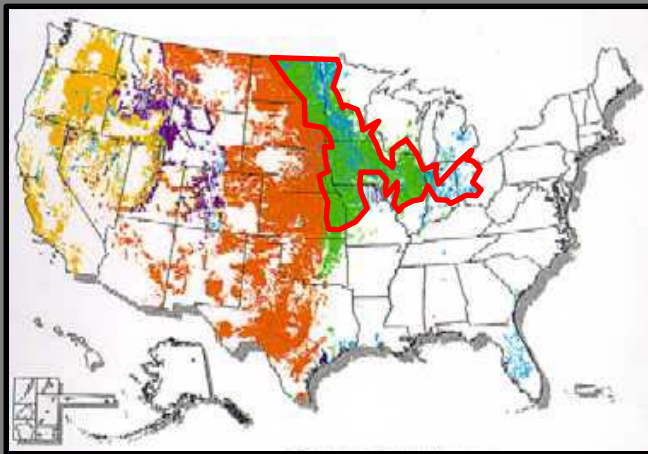
Bars represent  $\pm 1$  standard error;  $\text{Pr} > |t|$ ,  $\dagger p < 0.1$ ,  $* p < 0.05$ ,  $** p < 0.01$

# Arlington soils: Mollisols

Formed in deep loess (>1) deposits over calcareous glacial till

Vegetation dominated by tall grass prairie and oak savannah communities

- Highly productive
  - High SOC



*Mollic  
Epipedon*

*Photo courtesy of  
University of Nebraska*

# Total Soil Combustible C (g/kg) averaged over 2001 and 2002 at the conclusion of 9-yr cropping systems comparison

(Teasdale et al, 2007)

	<b>15-30 cm</b>	<b>7.5-15 cm</b>	<b>15-30 cm</b>
No-Tillage	7.1b	11.1c	7.1b
Cover Crop	7.8b	12.4b	7.8b
Organic	10.3a	15.9a	10.3a

# Soil Carbon Sequestration

## USDA Farming Systems Project, MD

System	C to 1 m soil depth (Mg C/ha)	Change in Soil C (kg CO <sub>2</sub> ha <sup>-1</sup> y <sup>-1</sup> )
No Till	54.9b	0b
Chisel Till	51.7b	-1080c
Organic	60.8a	1953a

# ISU Neely-Kinyon LTAR Site, Greenfield, IA (Long-Term Agroecological Research)



Quarter-acre plots (oats/alfalfa)



Forty-four plots—four rotations—five crops

# After 12 years, soil quality higher in organic system

Fall 2009	Organic	Conventional
SOC (g/kg)	24.0a	22.9b
TN (g/kg)	2.3a	2.2b
POMC (g/kg)	4.0a	2.4b
MBC (mg/kg)	361a	296b
PotMinN (mg/kg)	60a	41b
InorgN (mg/kg)	3.8a	2.7a
Macroaggs (%)	27.8a	24.2a

- Depth 0-15 cm
- Organic C-S-O/A-A
- Conventional C-S

–C. Cambardella, USDA-ARS  
National Lab for Ag & the Environment

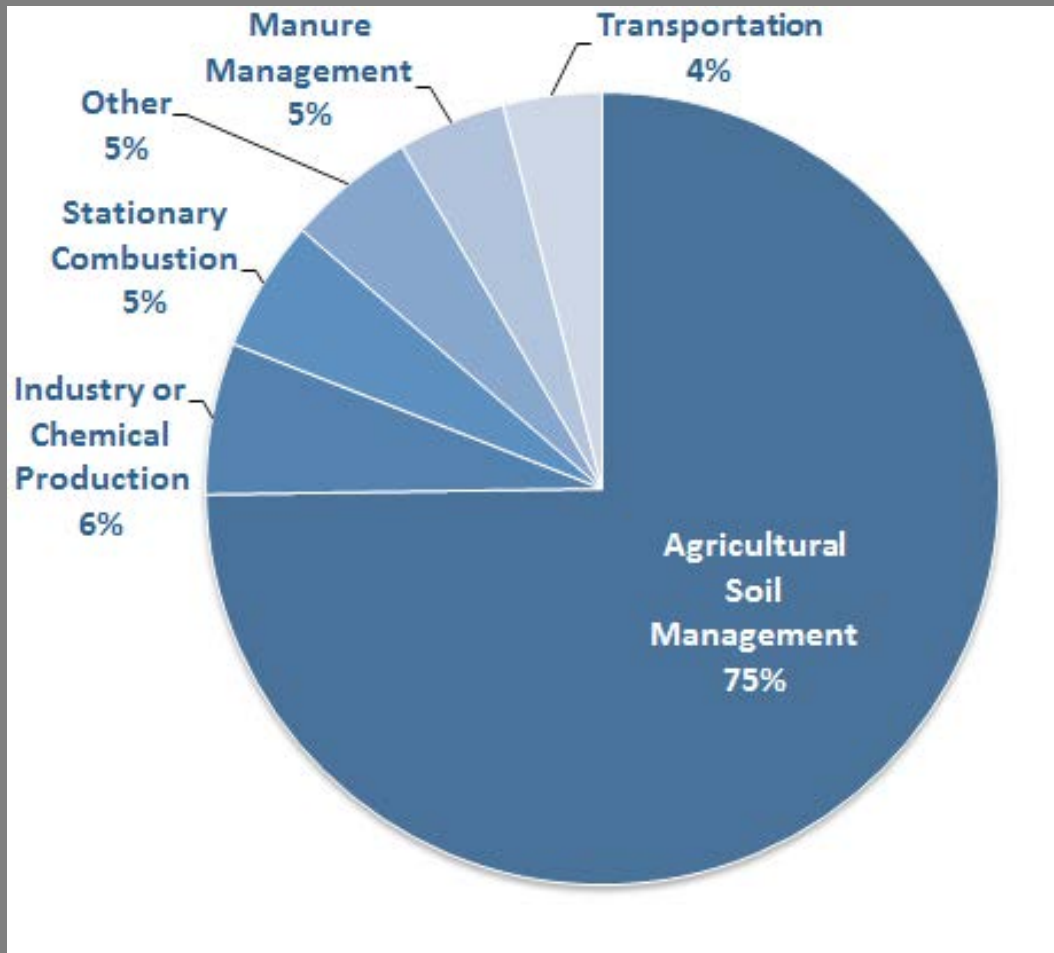
Means followed by same letter within a row are not different at 95% CI

# Swiss Study (FiBL)

(Gattinger et al., 2012)

- Meta-analysis of 74 studies
- Organic farming practices lead to increased SOC stocks in the upper 20 cm of soil over a period of *ca.* 14 y
  - $3.50 \pm 1.08 \text{ Mg C ha}^{-1}$  higher in organic than in nonorganic systems
  - Zero net input organic systems - significant and positive at  $1.98 \pm 1.50 \text{ Mg C ha}^{-1}$
- Soil C sequestration by switching to organic agriculture could offset 3% of current total GHG emissions (2.3% for Europe, 2.3% for the United States), or 25% of total current agricultural emissions (23% for Europe, 36% for the United States)

# U.S. Nitrous Oxide Emissions



# Nitrous Oxide

- Important contributor of in-field GHG emissions
- Emitted when nitrogen is added to the soil through fertilizers
- Emitted during the breakdown of nitrogen in livestock manure and urine
- GWP = 310

# Impact of cropping systems on N<sub>2</sub>O emissions

2013 Review article

(Butterbach-Bahl et al., 2013)

“Although it is well established that soils are the dominating source for atmospheric nitrous oxide (N<sub>2</sub>O), we are still struggling to fully understand the complexity of the underlying microbial production and consumption processes and the links to biotic (e.g. inter- and intraspecies competition, food webs, plant–microbe interaction) and abiotic (e.g. soil climate, physics and chemistry) factors.”

# N<sub>2</sub>O flux

- Gains in soil C may be offset by N<sub>2</sub>O emissions
  - 1N<sub>2</sub>O = 298 CO<sub>2</sub>
- NT  $\geq$  CT, soil type effect (Grandy et al., 2006; Rochette et al., 2008)
- Emissions of N<sub>2</sub>O in organic systems
  - = conventional (Robertson et al., 2000; Kramer et al., 2006)
  - < conventional (Dalgaard et al., 2002, 2003; Flessa et al., 2002; Peterson et al., 2006)

# Main drivers of nitrous oxide emissions

- Applications of nitrogen fertilizers
  - Both organic and synthetic
- Moisture and temperature of soils
  - Regulates microbes in nitrification and denitrification processes
- Poorer-draining clay-textured soils generally have higher denitrification and N<sub>2</sub>O losses
- Soil compaction

# Impacts of Fertilizer Applications

- IPCC default for N<sub>2</sub>O emissions factor (EF) of 1.0% of annual N fertilizer application
  - In the Midwest, emissions range between 0.2 and 6.3% (or more) of the fertilizer N applied
- Could potentially minimize impact by:
  - Synchrony between N supply and N demand
    - Ideally, N application closer to a crop's most active N uptake period
  - Improve Nitrogen Use Efficiency of system
    - Genetics and management

# “Seasonal Nitrous Oxide and Methane Fluxes from Grain and Forage-Based Production Systems in Wisconsin, USA”

(Osterholz, Kucharik, Hedtcke, and Posner, 2014)

- Compared  $\text{N}_2\text{O}$  and  $\text{CH}_4$  fluxes over the 2010 and 2011 growing seasons from the six cropping systems at the Wisconsin Integrated Cropping Systems Trial (WICST)

# Results

- Organic grain and minimum tillage corn–soy systems had lower area-based  $N_2O$  emissions than continuous corn
- Primary difference: both systems received lower rates of N addition across the full crop rotation
  - greater crop diversity and less frequent planting of corn
- Reduced N fertilizer rates may have driven the decreased emissions



# Recommendations from study

- Shift from high-input, continuous-corn systems to more diversified systems with longer rotations
- Shift from shorter rotation systems to longer rotations with less frequent N application
- Increase rotational pasture systems



# Diversity → less N<sub>2</sub>O emissions

- Drury et al. (2008) - showed reductions in emissions in more diverse cropping systems
- Parkin and Kaspar (2006) - showed that inclusion of a soybean year in a corn-based cropping system reduced N<sub>2</sub>O emissions
  - crop diversity - often associated with diversity in N demand and fertilizer application rates - can be a significant driver of reduced N<sub>2</sub>O emissions

# Nitrous Oxide Emissions from Corn USDA Farming Systems Project, MD (kg N<sub>2</sub>O -N ha<sup>-1</sup> y<sup>-1</sup>)

System	2005	2006	2007	2008	2010	Cumulative
No-Till	3.5	4.1a	0.67ab	1.0	0.8	10.1a
Chisel-till	2.3	3.4a	0.64b	1.1	1.3	8.7ab
Organic 3-year	2.9	1.9b	0.75a	1.3	1.4	8.3b
ANOVA P	ns	<0.05	<0.05	ns	ns	<0.1

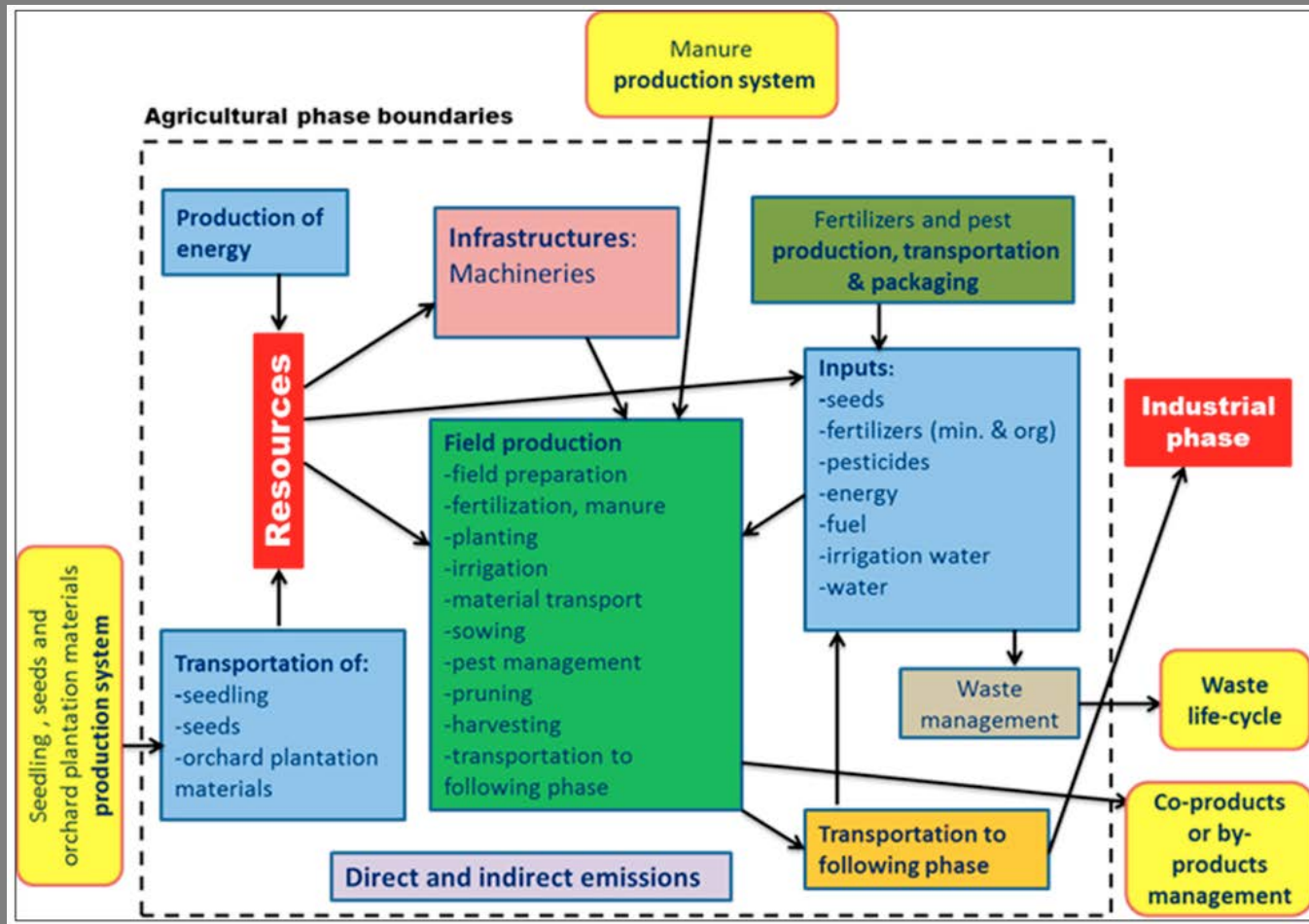
# Methane

- 25% - Ruminant domestic livestock (cattle, buffalo, sheep, goats, and camels)
- 9% - manure managed in lagoons or holding tanks, CH<sub>4</sub> is produced
- Studies have shown no significant differences in methane emitted from organic vs. conventional production systems (Robertson et al., 2000; Osterholz et al., 2014)

# LCIA: Life Cycle Impact Assessment

- The “what does it mean” step of life cycle analysis
- The global warming impact from combustion of that fuel is calculated
- Variables in LCIA include:
  - the system boundary (how far upstream, downstream and sidestream does the analysis go)
  - the functional unit (what is the volume/mass/purpose of the object being assessed)
  - allocation (how are impacts assigned to the product and by-products, on what basis)

# Concern of Boundaries



# Key aspects of LCIA

- Boundaries – where does the analysis start and end?
  - Production on inputs? Transportation of inputs?  
Transportation and storage of product?
- Functional unit – what are we comparing?
  - Emissions per land area? Per yield? Per cow? Per cwt of milk?

# Carbon Footprint of Grass-based vs. Confinement Dairy Systems

(O'Brien et al., 2014)

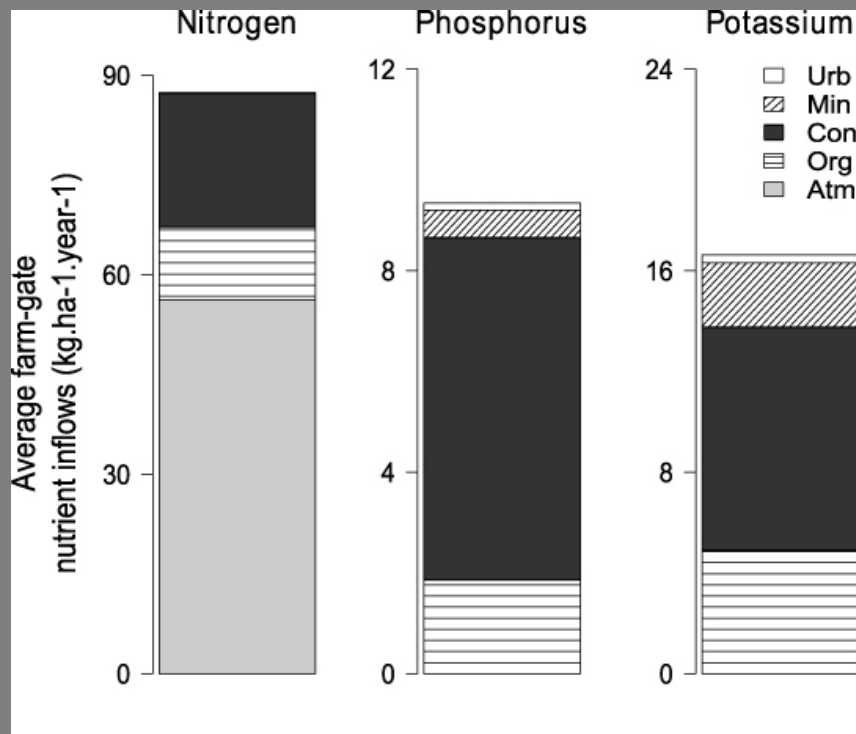
- Irish grass-based system – fed grass-silage produced on farm, concentrate purchased by the farm and fed when forage intake not sufficient to meet nutritional requirements (320 kg of DM per cow)
- UK and US confinement dairy systems – fed TMR or PMR diets, corn silage, alfalfa hay to maximize production

# Estimated Methane Emissions for Grass-based vs. Confinement Dairy

(CO<sub>2</sub>-eg/t of ECM)  
(O'Brien et al., 2014)

	Location	Grass-based	Confinement
Enteric Fermentation	On farm	430.69	373.60
Manure storage and spreading	On farm	42.09	121.91
Fertilizer Production	Off farm	1.61	0.39
Concentrate production	Off farm	0.82	1.55
Electricity and other inputs	Off farm	12.88	14.95
Carbon Sequestration	On farm	-77.72	0
CFP, kg CO <sub>2</sub> -eq/t of ECM	Total	837	898

# To what extent does organic farming rely on nutrient inflows from conventional farming?



- Organic agriculture – allows manure and compost derived from conventional systems
- These inflows represent transfers of nutrients initially contributed by manufactured fertilizers and have to be accounted for: (i) when comparing the environmental impacts of conventional and organic farming; and (ii) when designing scenarios of massive conversion to organic farming

# Strategies to Reduce Impact – Carbon Sequestration

- Reduce the frequency and intensity of soil tillage
  - Cover crop-based reduced till techniques for organic
- Including more hay crops in annual rotations
  - Below-ground biomass
- Production of high-residue-yielding crops and reduced fallow periods
  - Cover cropping
- Improved pasture management
- Conservation set-asides and restoration of degraded lands
- Use of manure as a fertility input

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# Additional Resources

Future webinars this series:

- **Biodiversity:** June 17<sup>th</sup>, 2:00 EST
- **Soil:** August 27<sup>th</sup>, 1:00 EST
- **Water Quality:** September 23<sup>rd</sup>, 3:00 EST

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