Impact of Grain Farming on Climate Change

Michel A. Cavigelli

USDA-ARS Sustainable Agricultural Systems Lab
Beltsville Agricultural Research Center, MD

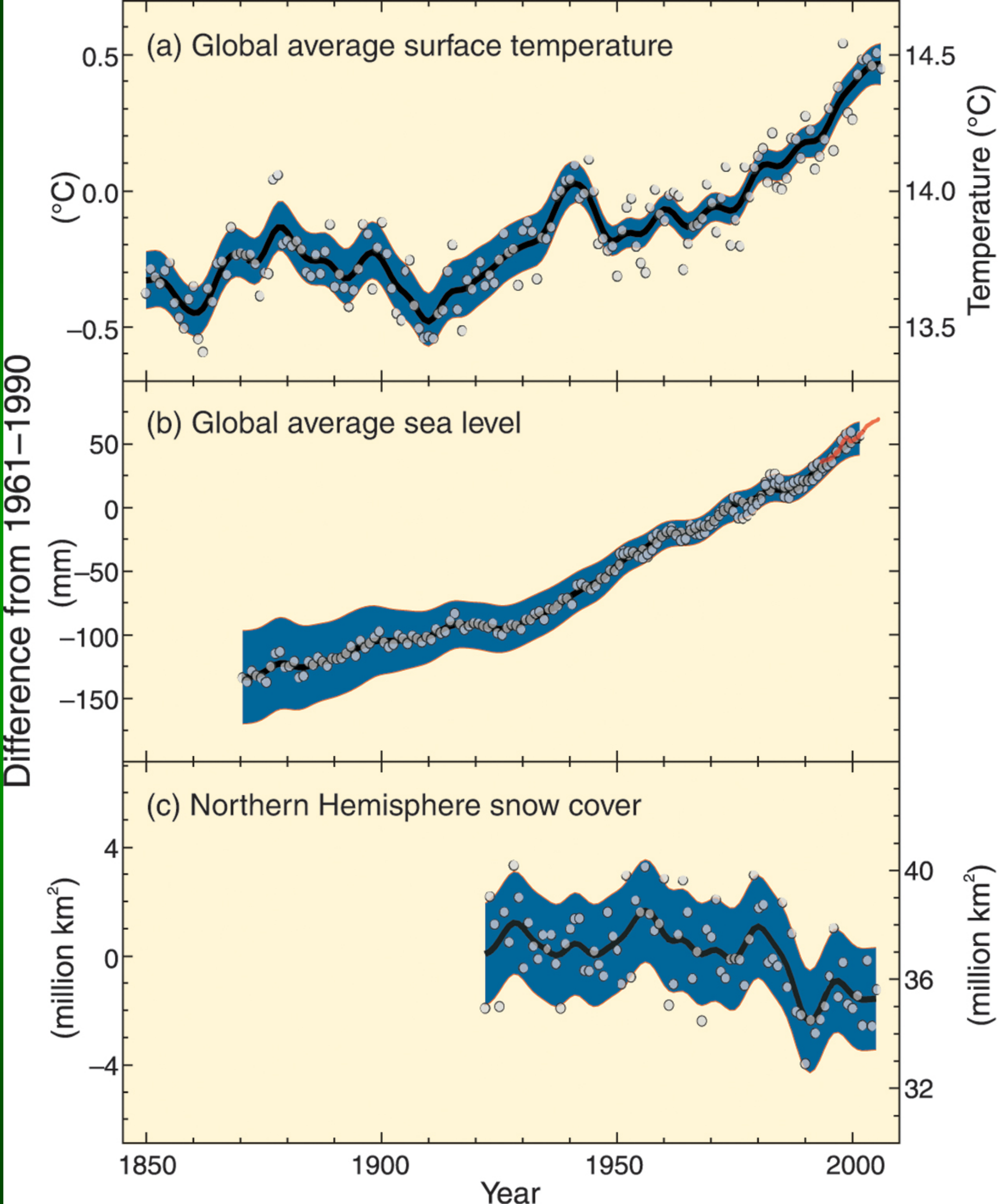
USDA ars **Agricultural Research Service**
the in-house research arm of the U.S. Department of Agriculture

Presented at Nutrient Managers Webinar, March 22, 2016

Outline

1. Global warming and greenhouse gases
2. Agricultural impacts on GHGs
3. Global Warming Potential--what is it and how to measure it
4. GWP of diverse cropping systems in Maryland

Global Warming



IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Atmospheric Greenhouse Gases (GHGs)

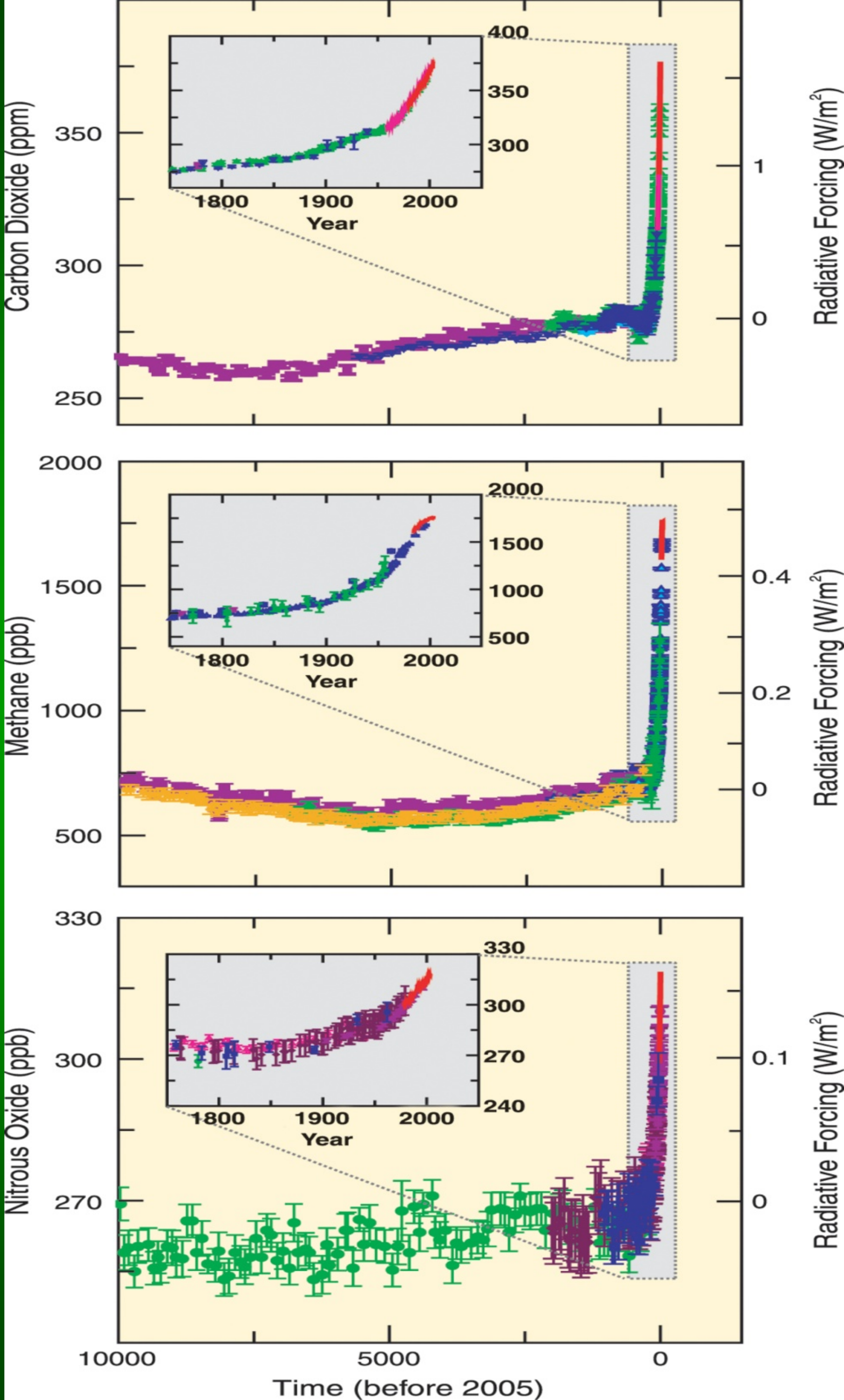


Figure 2.3. Atmospheric concentrations of CO_2, CH_4 and N_2O over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings relative to 1750 are shown on the right hand axes of the large panels.

IPCC. 2007.

CO_2 equivalents

- GHGs expressed as CO_2 equivalents ($CO_{2\ eq}$)
  - $N_2O \times 298 = CO_{2\ eq}$
  - $CH_4 \times 25 = CO_{2\ eq}$

Atmospheric GHGs

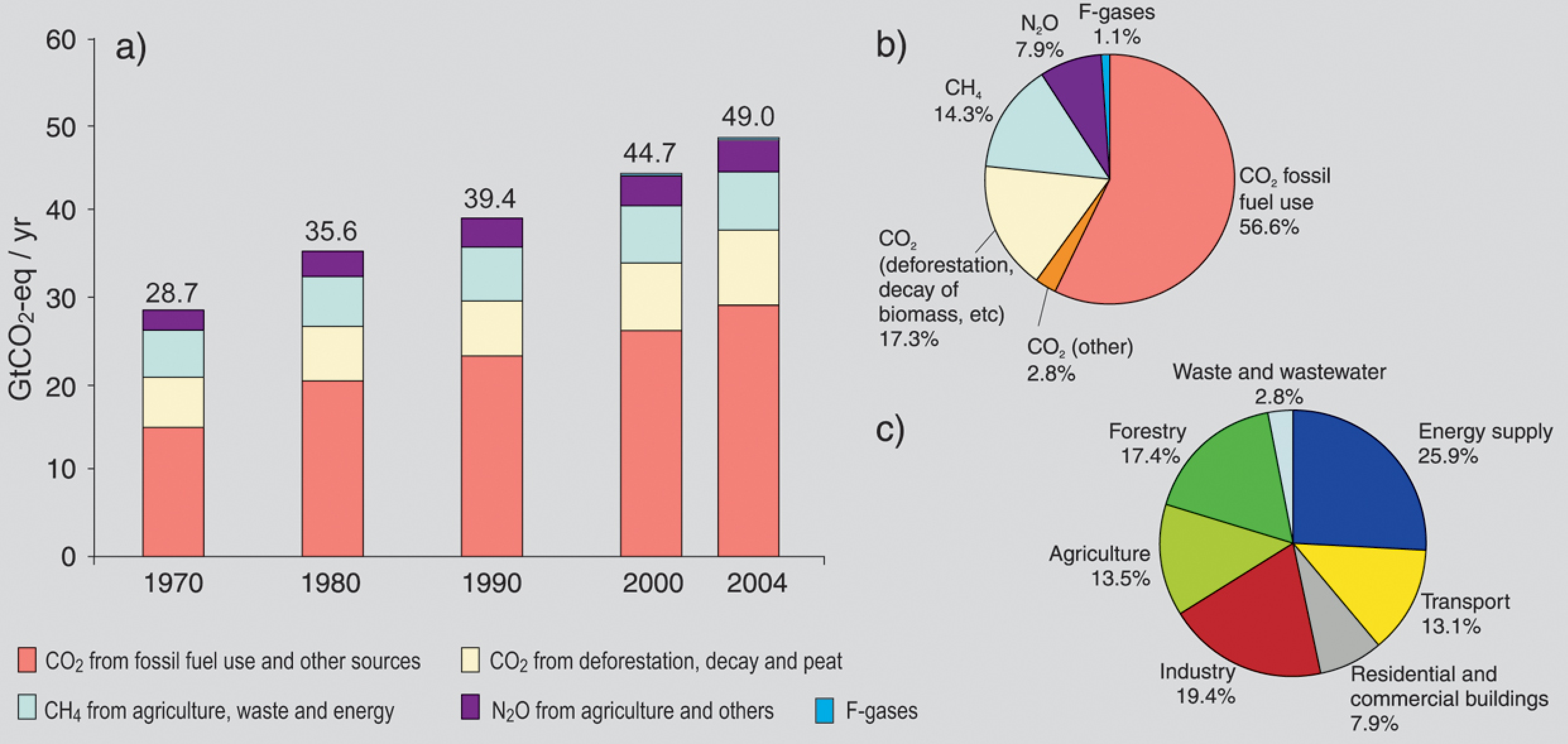


Figure 2.1. (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004. (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq. (Forestry includes deforestation.)

IPCC. 2007.

GHGs and Agriculture

- Agricultural lands occupy 40-50% of Earth's land surface (cropland, managed grasslands, permanent crops)

GHG	$GtCO_2$-eq/yr	% of total anthropogenic GHG emissions
CO_2	5.1-6.1	<1
CH_4	3.3	~50
N_2O	2.8	~60

- Agricultural CH_4 and N_2O increased ~17% from 1990 to 2005

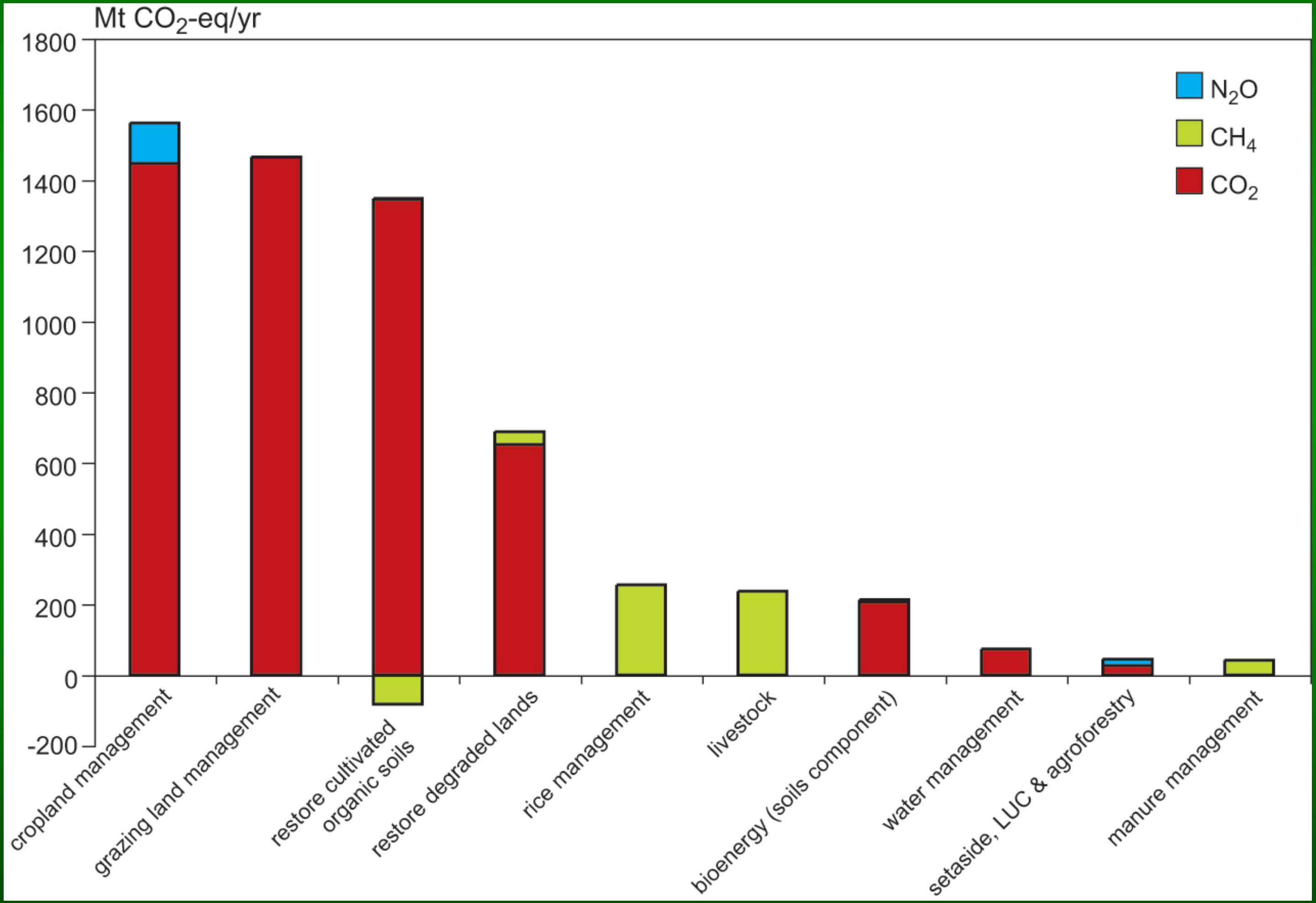
IPCC. 2007.

Agriculture and Mitigation of GHG Emissions

- Unlike industrial mitigation options, many agricultural mitigation options:
  - use existing technologies
  - could be implemented immediately
    - E.g.: Reducing tillage, increasing carbon inputs to soil, improving N fertilizer use efficiency, improving livestock management

IPCC. 2007.

Agriculture and Mitigation of GHG Emissions



IPCC. 2007.

Global Warming Potential

- GWP = the balance between the net exchange of CO_2, N_2O and CH_4 that results from on-farm practices and the production and transport of inputs

  (Robertson and Grace, 2004)

  - $GWP > 0$
    - activity contributes to global climate change
  - $GWP < 0$
    - activity mitigates global climate change
  - Agriculture has the potential to have $GWP < 0$

Global Warming Potential

- GWP = ΔSoil C + N_2O flux + CH_4 flux + Energy Use

- Each converted to CO_2 equivalents ($CO_{2\ eqvt}$)
  - Soil C x 44/12 = $CO_{2\ eqvt}$
  - N_2O x 298 = $CO_{2\ eqvt}$
  - CH_4 x 25 = $CO_{2\ eqvt}$
  - Energy use: On-farm practices and production and transport of material inputs converted to $CO_{2\ eqvt}$

(Lal 2004, Dalgaard et al. 2001, IPCC 1996, 2001, Bowers 1989)

Cropping System Impacts

GWP = Δ**Soil C** + N_2O flux + CH_4 flux + Energy Use

- NT > CT (many citations, conventional wisdom)
- NT soil C lost quickly following one tillage event

  (Grandy and Robertson, 2006a, b)
- Little data on organic systems

Cropping System Impacts

GWP = Δ**Soil C** + **N_2O flux** + CH_4 flux + Energy Use

- Gains in soil C may be offset by N_2O emissions

  ($1\ N_2O = 298\ CO_2$)

- NT $\geq$ CT, soil type effect
  (Grandy et al, 2006; Rochette et al, 2008)

- Very few data on soil N_2O emissions from
  - cropping systems in SE USA
    (Franzluebbers, 2005)
  - organic systems
    (Robertson et al, 2000)

Cropping System Impacts

GWP = Δ**Soil *C*** + N_2O flux + CH_4 flux + Energy Use

- Most studies report no cropping system impacts

  (Robertson et al. 2000, Robertson and Grace 2004)

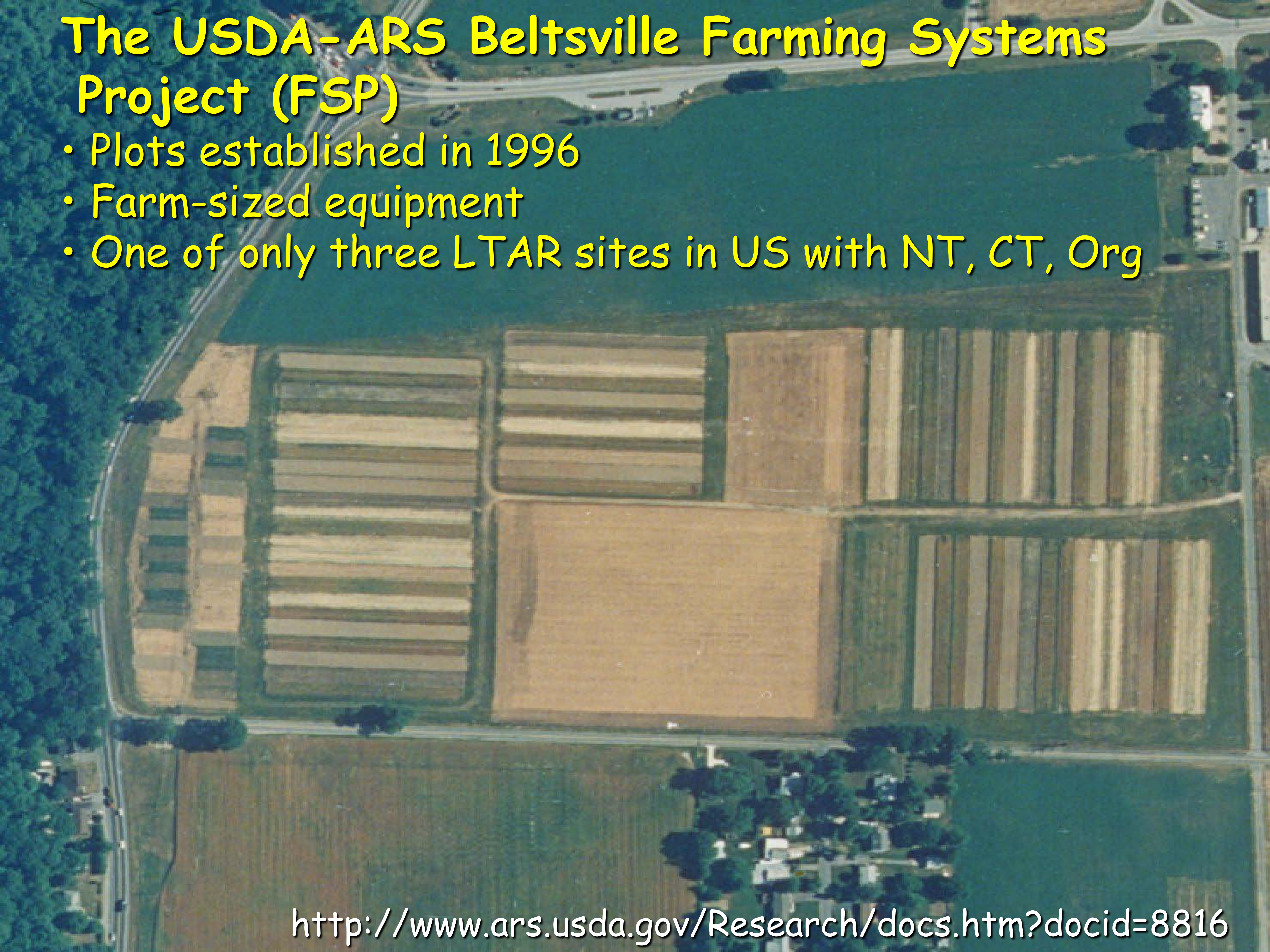
- GWP = ΔSoil *C* + N_2O flux + Energy Use

Cropping System Impacts

GWP = Δ**Soil C** + N_2O flux + CH_4 flux + Energy Use

- NT < CT
  - reduced tillage > increased herbicides
- Organic < CT
  - no synthetic N fertilizers (~30% energy use in agriculture)
  - essentially no pesticides
  - greater tillage
- NT vs Organic – very few comparisons

The USDA-ARS Beltsville Farming Systems Project (FSP)



- Plots established in 1996
- Farm-sized equipment
- One of only three LTAR sites in US with NT, CT, Org

http://www.ars.usda.gov/Research/docs.htm?docid=8816

FSP Cropping Systems

NO TILL	Corn-*rye*-Soybean-Wheat/Soybean
CHISEL TILL	Corn-*rye*-Soybean-Wheat/Soybean
ORGANIC, 2-YEAR	Corn-*rye*-Soybean-*vetch*
ORGANIC, 3-YEAR	Corn-*rye*-Soybean-Wheat/*vetch*
ORGANIC, 6-YEAR	Corn-*rye*-Soybean-Wheat/Alfalfa

- Sidedress N fertilizer band-injected in NT, CT
- Moldboard plow, poultry litter used in organic systems
- All rotation entry points present each year

Methods—Soil C (2006)

0-2.5 cm
2.5-5 cm
5-10 cm
10-25 cm
25-50 cm
50-100 cm

Dry combustion

Methods—N_2O flux

CT, NT, Org3

2 frames plot^{-1}

Jan-Dec

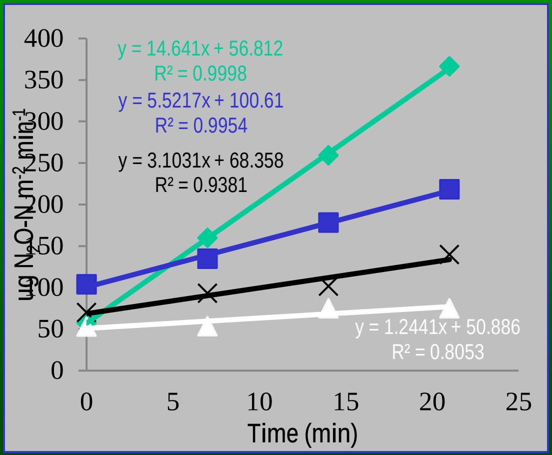
2005 to 2008, 2010

22-34 samplings yr^{-1}

4 samples within

12 to 21 mins

Gas chromatography



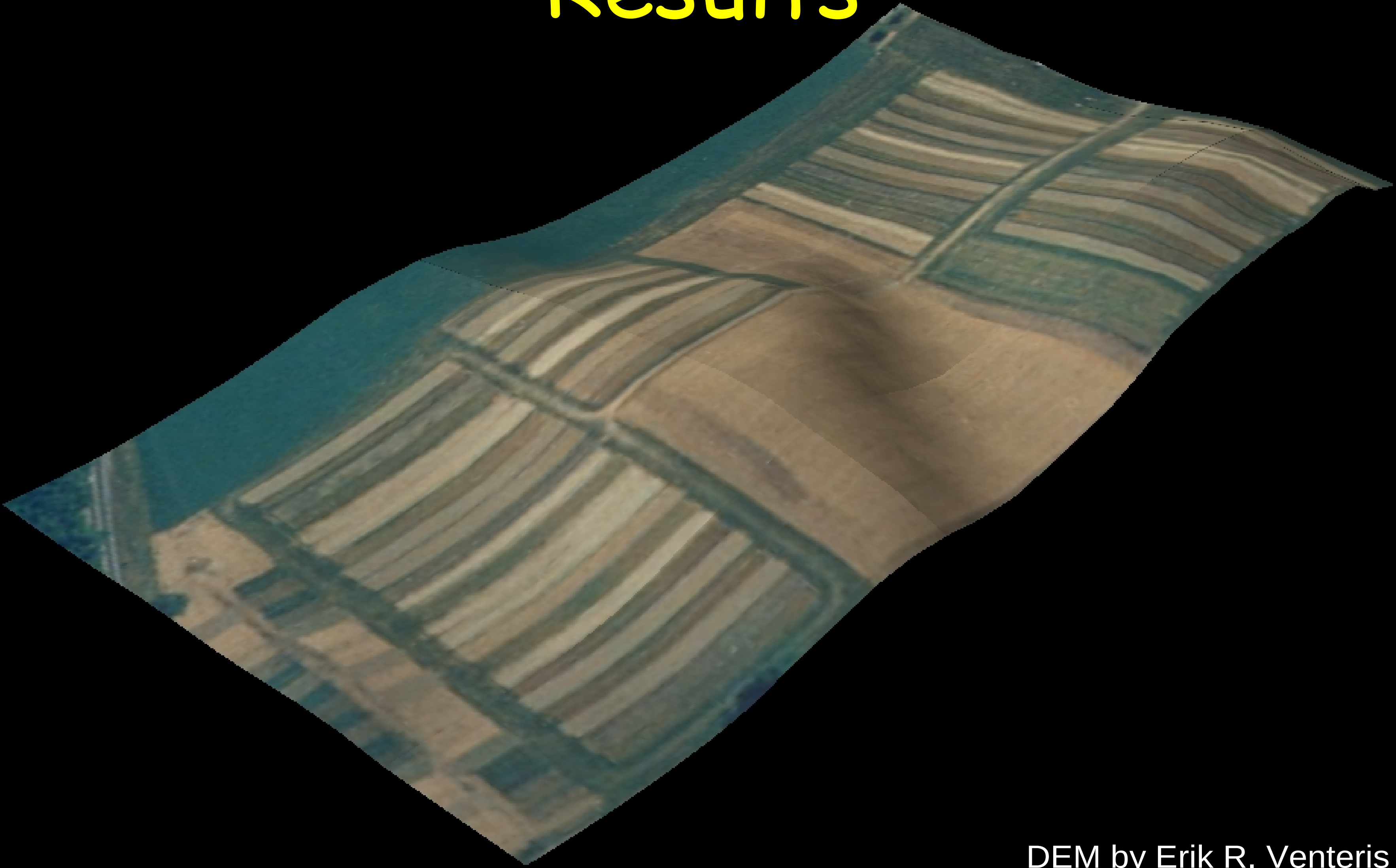
Methods—Energy Use

Corn, 2008, Machinery component

Operation	CE value* (kg CE ha^{-1} pass^{-1})	NT	CT	Org3
Moldboard Plow	20.0			1
Chisel plow	12.7		1	
Disking after MB plow	9.23			2
Disking	6.83		4	
Field Cultivator	4.00		1	1
Planter	2.91		1	2
No-Till Planter	2.35	1		
Rotary Hoe	2.00			2
Row Cultivator	4.00			3
Sidedress N	10.1	1	1	
Pesticide Application	1.40	2	1	1
Harvest	10.0	1	1	1
TOTAL		25	55	73

* Lal 2004, Bowers, 1989

Results

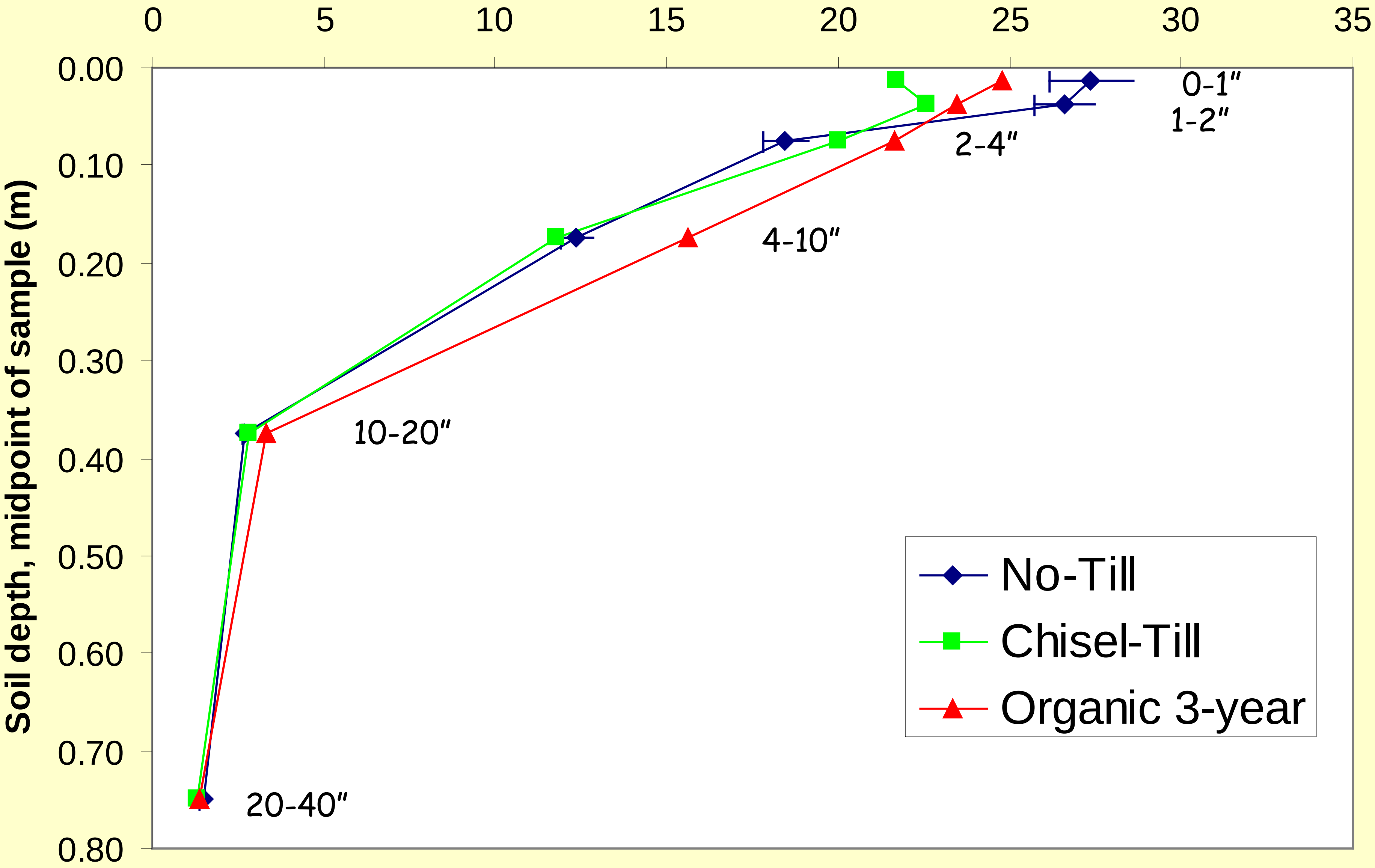


DEM by Erik R. Venteris

Soil Carbon

	C to 1 m soil depth	ΔSoil C
System	Mg C ha^{-2}	kg CO_2 eqvt ha^{-1} y^{-1}
No till	54.9 b	0 b
Chisel till	51.7 b	-1080 c
Organic	60.8 a	1953 a

Total soil C (kg C m^{-3})



Nitrous oxide (N_2O)—Corn

System	$\text{kg } N_2O\text{-N ha}^{-1}\text{ y}^{-1}$ 2005	2006	2007	2008	2010*	Cumulative	Cumulative N_2O-N as % Total N inputs
No-Till	3.5	4.1 a	0.67 ab	1.0	0.8	10.1 a	0.92 b
Chisel-till	2.3	3.4 a	0.64 b	1.1	1.3	8.7 ab	0.77 b
Organic 3-year	2.9	1.9 b	0.75 a	1.3	1.4	8.3 b	0.60 a
ANOVA P	NS	<0.05	<0.05	NS	NS	<0.1	<0.05

*through Oct. 15

Suggests that N_2O flux does not reflect total N inputs (contrary to findings of others)

Nitrous oxide, 2008

	kg N_2O-N ha^{-1} y^{-1}			
System	Corn	Soybean	Wheat	Full Rotation
No-Till	0.9	0.4	0.6 b	0.7 b
Chisel-till	1.1	0.8	0.8 b	0.9 ab
Organic 3-year	1.3	1.0	2.4 a	1.6 a
ANOVA P	NS	NS	<0.05	<0.05

Energy Use

Corn

	CO_{2eqvt}		
	(kg $CO_{2\ eqvt}$ ha^{-1} y^{-1})		
Input	NT	CT	Org3
Machinery	77	202	334
Nutrients	909	909	26*
Seed	84	84	99
Herbicides	92	59	0
Total	1162	1250	458

* Assumes poultry litter produced on-farm; if transported 114 to 127 km, total $CO_{2\ eqvt}$ for Org3 = NT and CT, respectively.

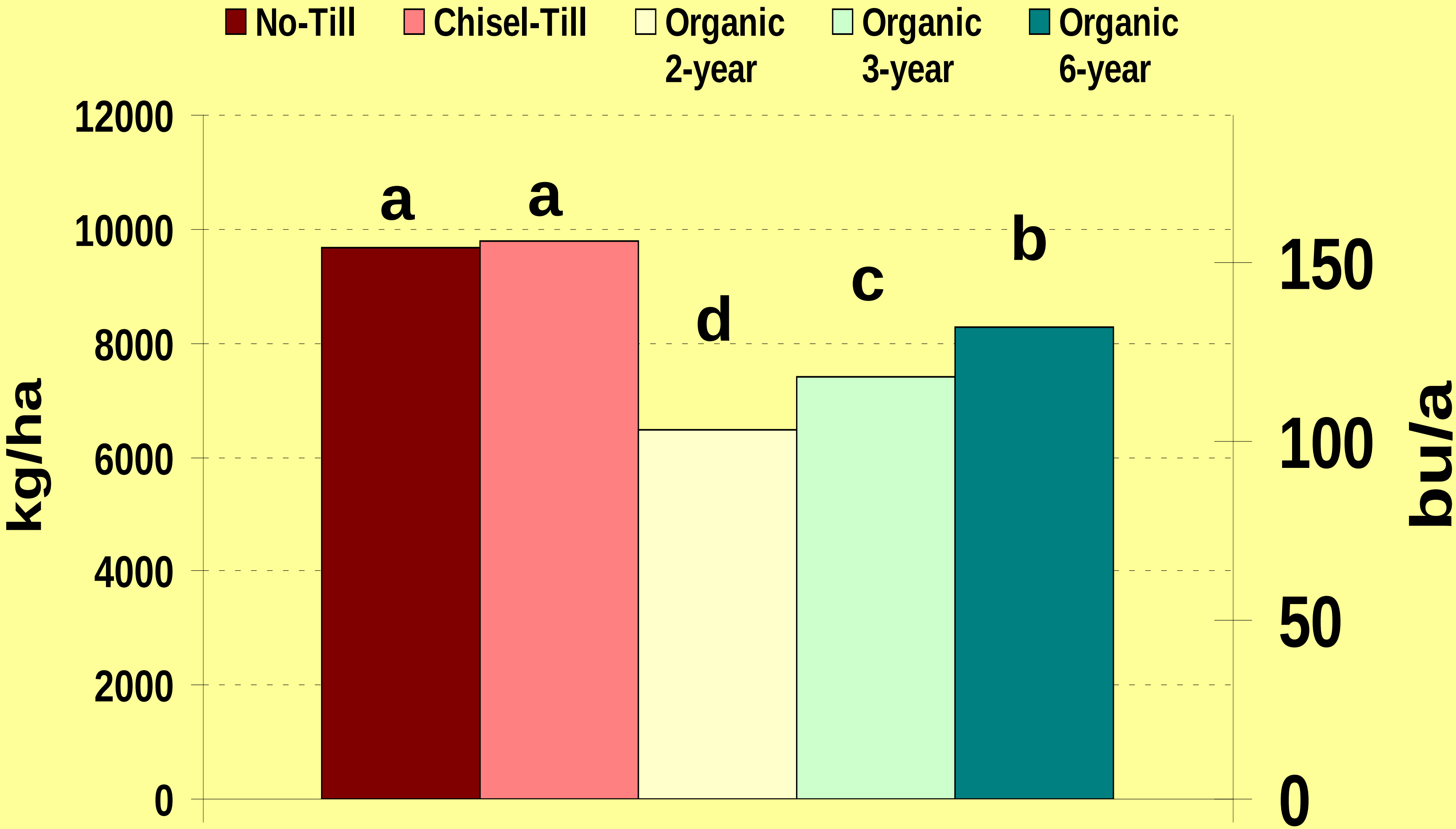
Energy Use

	$CO_{2\ eqvt}$ (kg CO_{2eqvt} ha^{-1} y^{-1})		
System	NT	CT	Org3
Corn	1162	1250	458
Soybean	506	576	403
Wheat	752	759	172
Full Rotation	807	862	344

Global Warming Potential

	$CO_{2\ eqvt}$ (kg CO_{2eqvt} ha^{-1} y^{-1})			
System	ΔSoil C	N_2O	Energy	GWP
No-Till	0 b	303 b	807	1110 b
Chisel Till	1080 a	406 ab	862	2348 a
Organic	-1953 c	737 a	344	-872 c

Average Corn Yields*



*years with normal rainfall

Greenhouse Gas Intensity

System	GWP (kg CO_{2eqvt} ha^{-1} y^{-1})	Crop Yield (Mg ha^{-1} y^{-1})	GHGI (kg CO_{2eqvt} Mg $grain^{-1}$)
No-Till	1110 b	7.25 a	153 a
Chisel Till	2348 a	7.14 a	330 a
Organic	-872 c	5.12 b	-169 b

Conclusions—Soil C

- Organic > NT, CT
- C sequestered at depth should be more stable than in surface of NT soils
- Need to include diverse cropping systems in LTARs to fully evaluate soil C sequestration options (GRACEnet)

Conclusions—N_2O flux

- Manure application contributed to high N_2O flux in Org3 in 2008
- Need additional data years for N_2O flux since it has high interannual variability

Conclusions—Energy Use

- NT, CT >> Org3
- Energy use in Org3 strongly controlled by manure transport distance

Conclusions—GWP, GHGI

- GWP
  - CT > NT > Org3 Org3 < 0
- GHGI
  - CT = NT > Org3 Org3 < 0

(despite high N_2O in 2008)

- Differences driven primarily by soil C
- Differences driven secondarily by energy use
- How we grow crops impacts global warming potential of agriculture
- Mitigation options can be implemented

Conclusions—Mitigation Options

- Each component of GWP can be targeted to reduce climate change impacts of agriculture: ΔSoil C, N_2O flux, Energy Use
  - NT provides mitigation compared to CT largely due to soil C sequestration
  - Burying C, however, may provide more C sequestration potential than NT
  - Reducing N fertilizer inputs may have bigger mitigating impact via reduction in CO_2 emitted during production and transport than N_2O emissions after application

Conclusions—Mitigation Options

- Mitigation strategies have multiple benefits
  - Soil C provides multiple soil health benefits
    - Improved water infiltration
    - Improved soil resilience to erosion and runoff
    - Improved nutrient recycling
  - Improving NUE is primary strategy to reduce N_2O emissions
    - Tends to reduce all N loss mechanisms
    - Reduces input costs
  - Reducing energy use has economic benefits
  - Mitigating GHG emissions = conservation