Organic Benefits and Challenges in the Face of Climate Change




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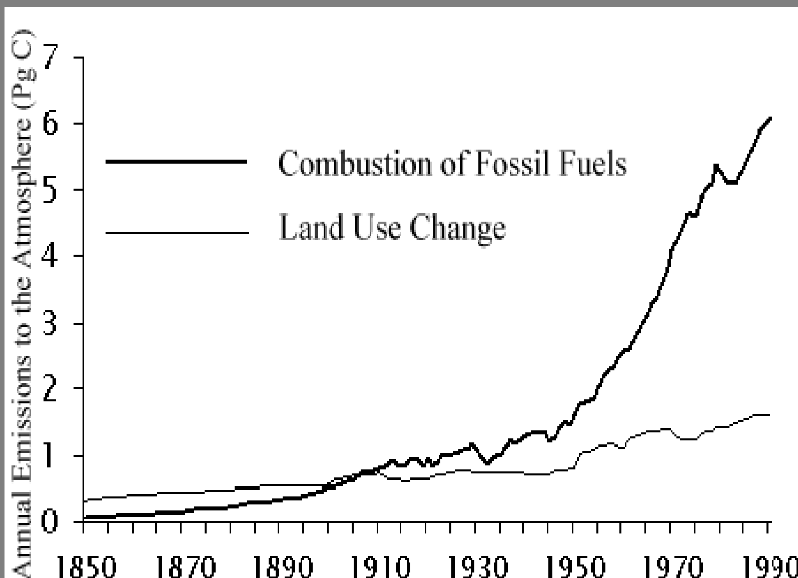
Outline of Presentation

- Global C budget
- Organic agriculture
- Wisconsin Integrated Cropping Systems Trial
- Impact of organic production systems on soil carbon
- Relevancy for semi-arid climates
- Conclusions

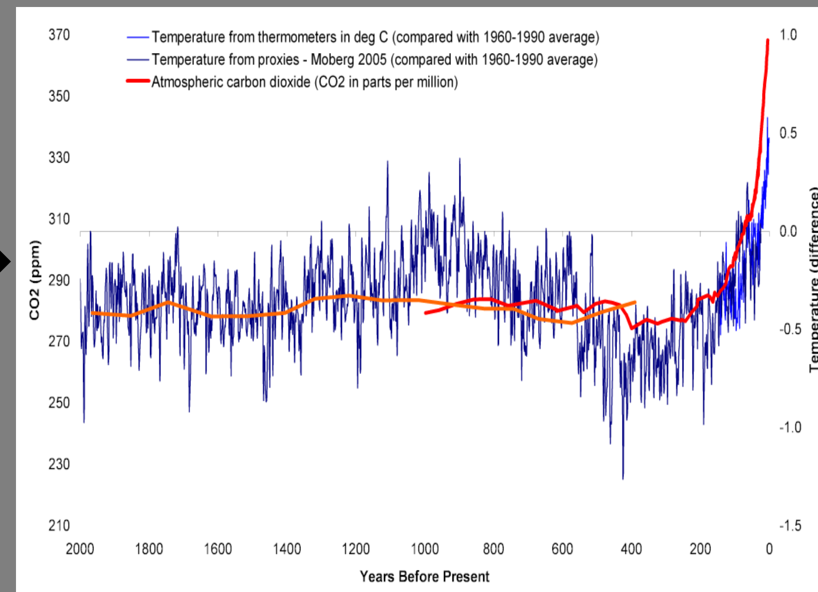
Agriculture, carbon & the climate

Source of C emissions



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

CO_2 & climate change



Moberg et al. 2005

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

Agriculture, the global C budget, and climate change

CO_2 mitigation via agriculture

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

Attractive mitigation option

- Immediately implementable
- Cost-effective

Policy & rural economy

- Cap & Trade – Chicago Climate Exchange (CCX)
- Ecosystem service subsidies

Organic Agriculture

- Regulations set by the US National Organic Program
- Requires three year transition period
- Set of specific production practices – more than not spraying pesticides and not using synthetic fertilizer

Organic Regulations Re: Soil Building

- Section 205.203(a): Select and implement tillage and cultivation practices that maintain or **improve the physical, chemical, and biological condition** of soil and **minimize soil erosion**
- Section 205.203(b): Manage crop nutrients and soil fertility through **rotations, cover crops**, and the application of plant and animal materials

How can agriculture influence climate change, particularly with respect to CO_2 and global C budget? How do our production practices (and particularly organic production practices) specifically influence SOC?

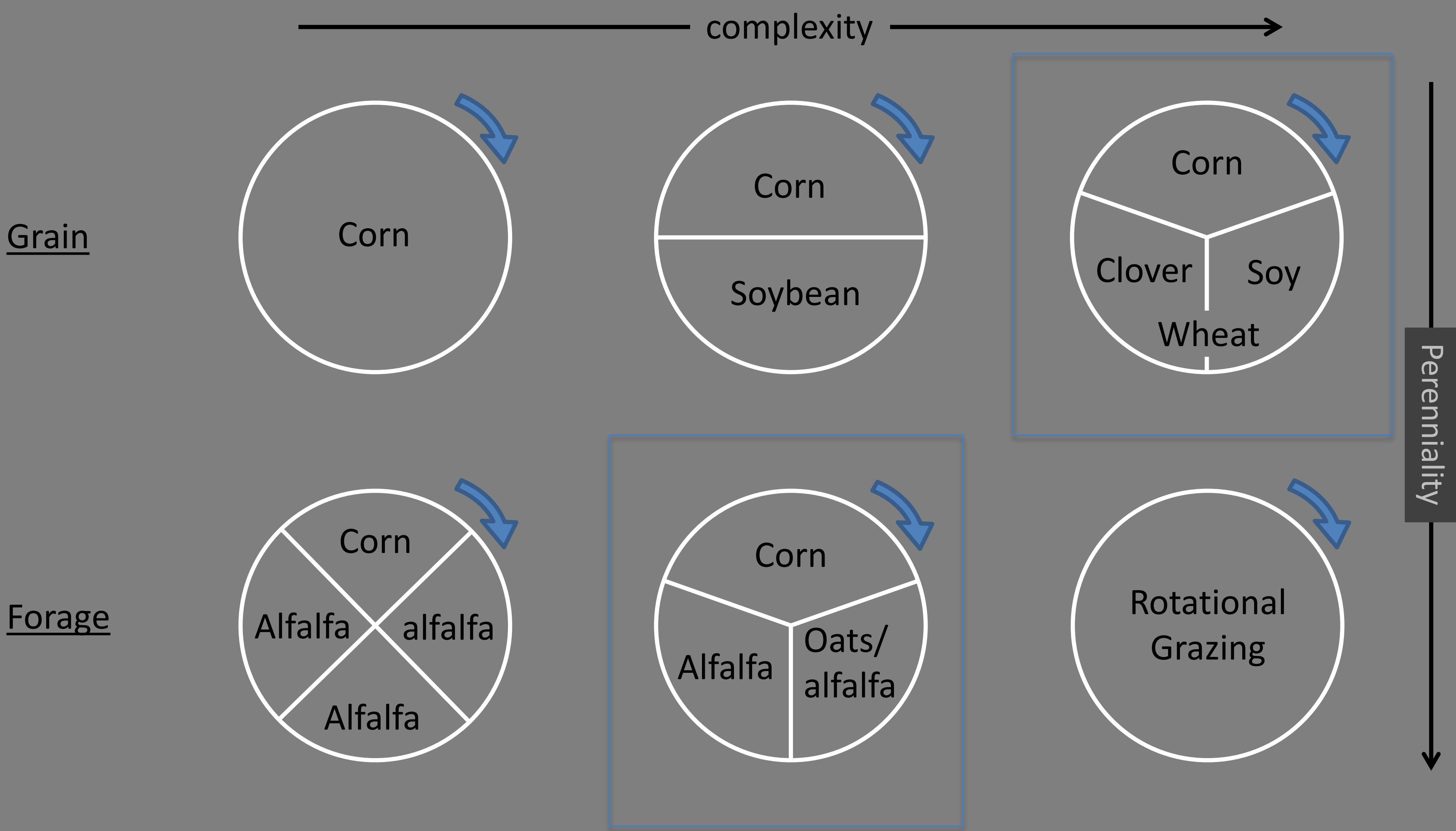
The Wisconsin Integrated Cropping Systems Trial

Arlington, WI

The Wisconsin Integrated Cropping Systems Trial (WICST)

- UW Ag. Research Station
  - Arlington, WI
  - Lakeland, WI
- 0.7 -acre plots – field scale equipment
- Silt loams
- In dairy rotation
  1850 - 1989
- WICST established
  1989 - 1990
- RCB with 4 blocks

WICST Cropping Systems

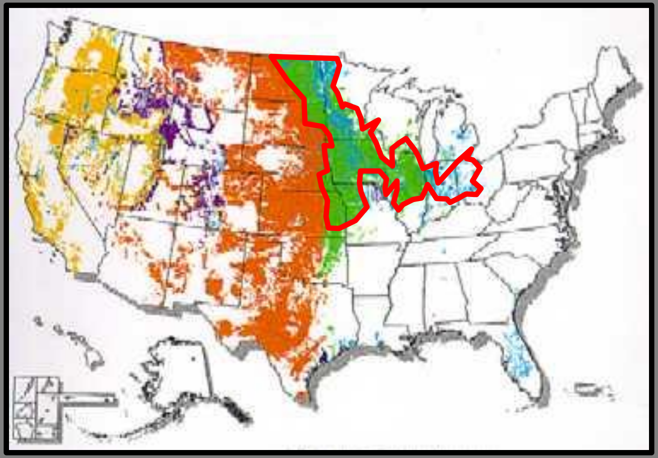


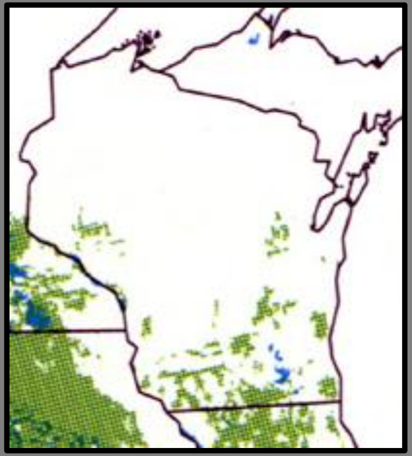
Arlington soils: Mollisols

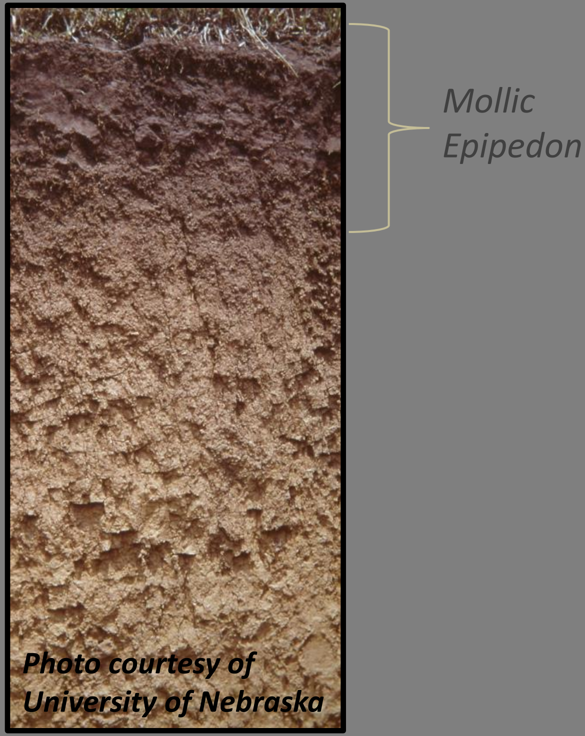
Formed in deep loess (>1) deposits over calcareous glacial till

Vegetation dominated by tall grass prairie and oak savannah communities

- Highly productive
  - High SOC








http://ngm.typepad.com/photos/uncategorized/2008/01/02/0103_os.jpg

Historic loss of SOC

c. 1850 - present

Wisconsin

Grace et al. 2006

- 14 % SOC lost
- Sampled 0 - 10 cm

Arlington, WI

Collins et al. 1999

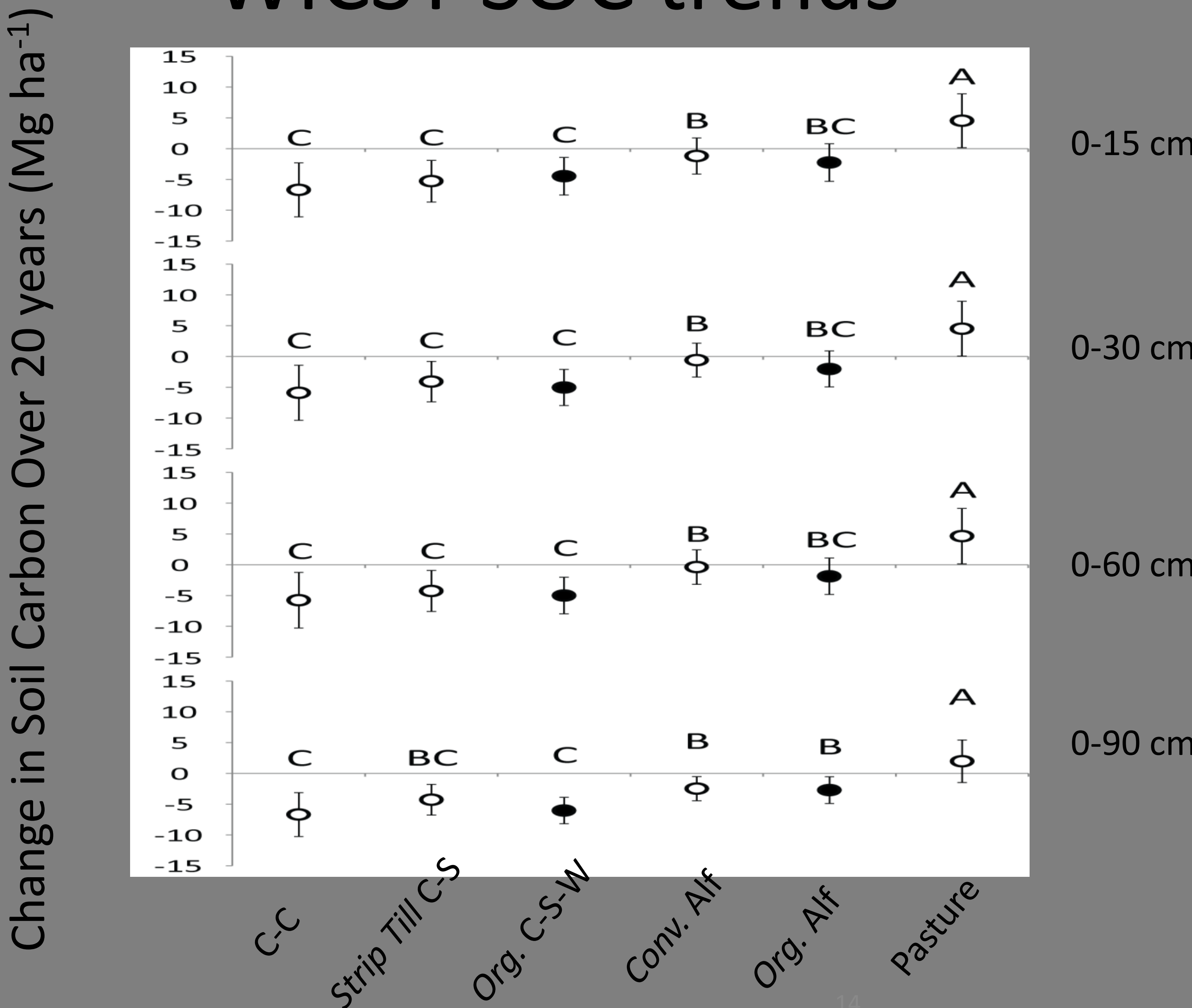
- 18% SOC lost
- Sampled 0 - 20 cm

Globally: 30 - 50% of SOC lost (Lal 2008; Ogel et al. 2005)

http://www.kansasmemory.org/item/7878

NCSU photo: http://iowahomestead.wordpress.com/

WICST SOC trends



Bars represent ±1 standard error; Pr>|t| , † p<0.1, * p<0.05, ** p<0.01

Soil C inputs on WICST

Group	System	Description	Estimated Annual C Input		
			Above Ground	Below Ground	Root / Shoot
			------------ (kg ha^{-1}) ------------		
Grain	CS1	continuous corn	3800	2240	0.58
	CS2	corn-soybean	2940	1670	0.56
	CS3	organic grain	2240	1200	0.54
Forage	CS4	conventional forage	3050	3840	1.25
	CS5	organic forage	3220	4010	1.24
	CS6	pasture	1590	4570	2.87

WICST SOC trends

General SOC ($g\ kg^{-1}$) trends

	Δ g kg^{-1}	Sign.
NT vs. Tilled	**2.8**	†
Forage vs. Grain	**3.2**	*

SOC ($g\ kg^{-1}$) correlations

		------ Estimated C inputs------	
Tillage	Manure	Aboveground	Belowground
---------------------------------- r ----------------------------------			
- **0.10***	**0.13****	-0.05	**0.11****

Pr>\|t\|, ns=not significant, † $p<0.1$, * $p<0.05$, ** $p<0.01$

Organic Agriculture and Tillage

- Organic farmers – cannot use herbicides
- Rely heavily on tillage and cultivation for weed management

Phases of Cover-Crop Based No-Till

1. Cover crops seeded the previous fall

3. Grain or seed crop no-till drilled into killed cover crop

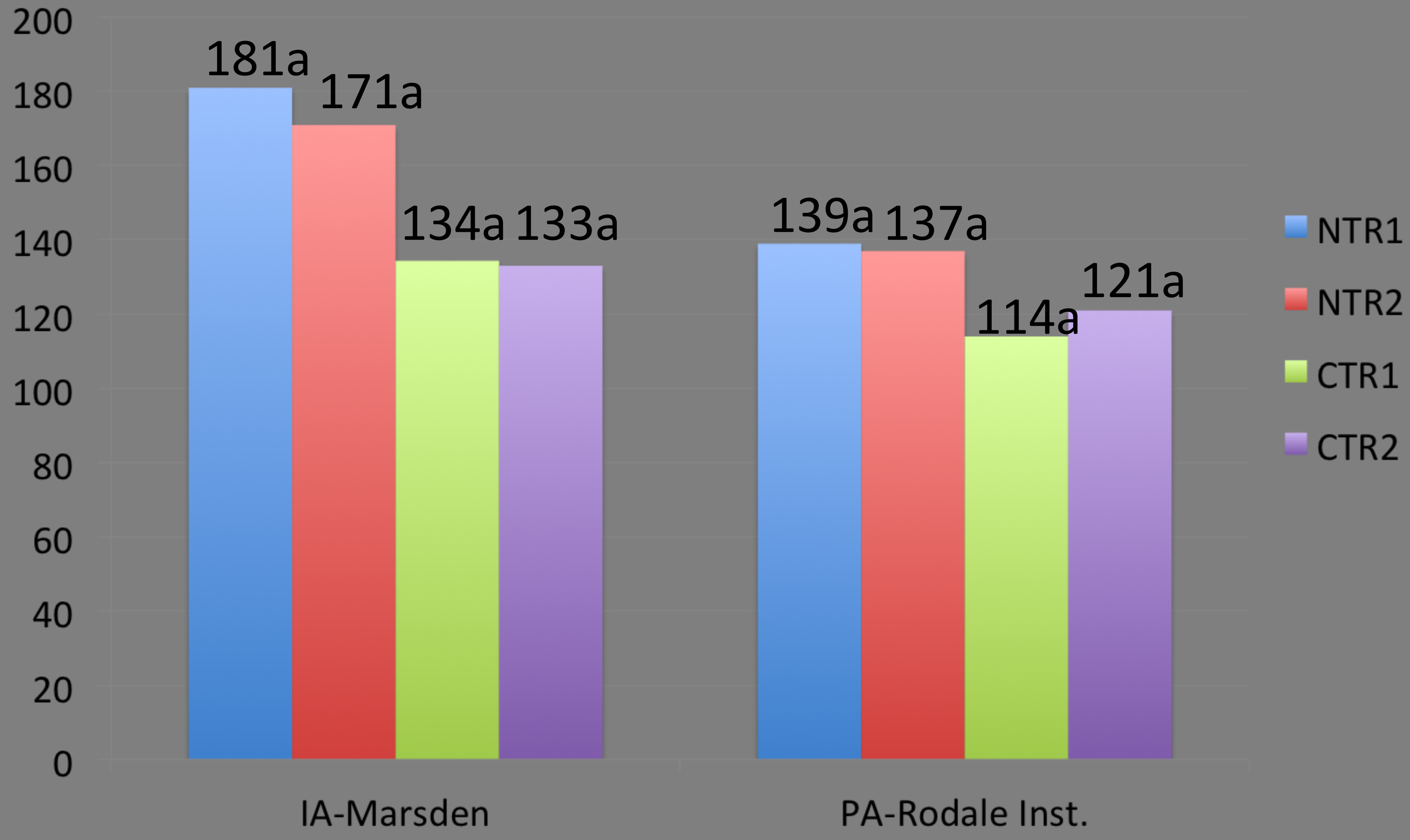
2. Cover crops killed in June

4. Grain or seed crop is combined

Images courtesy of Kathleen Delate at Iowa State Univ., and Dale Mutch at Michigan State Univ.

Soybean – end of July

Microbial biomass C-Fall 2011



Conclusions & Implications

- SOC: loss is rapid (140 yr), accretion is slow (~3000 yrs)
- WICST: best management ≠ SOC sequestration
- Below ground C allocation crucial to sequestration
  - Quantity & quality
- SOC stabilization:
  - f (C input > C oxidation) + sufficient time

Conclusions & Implications

Agricultural

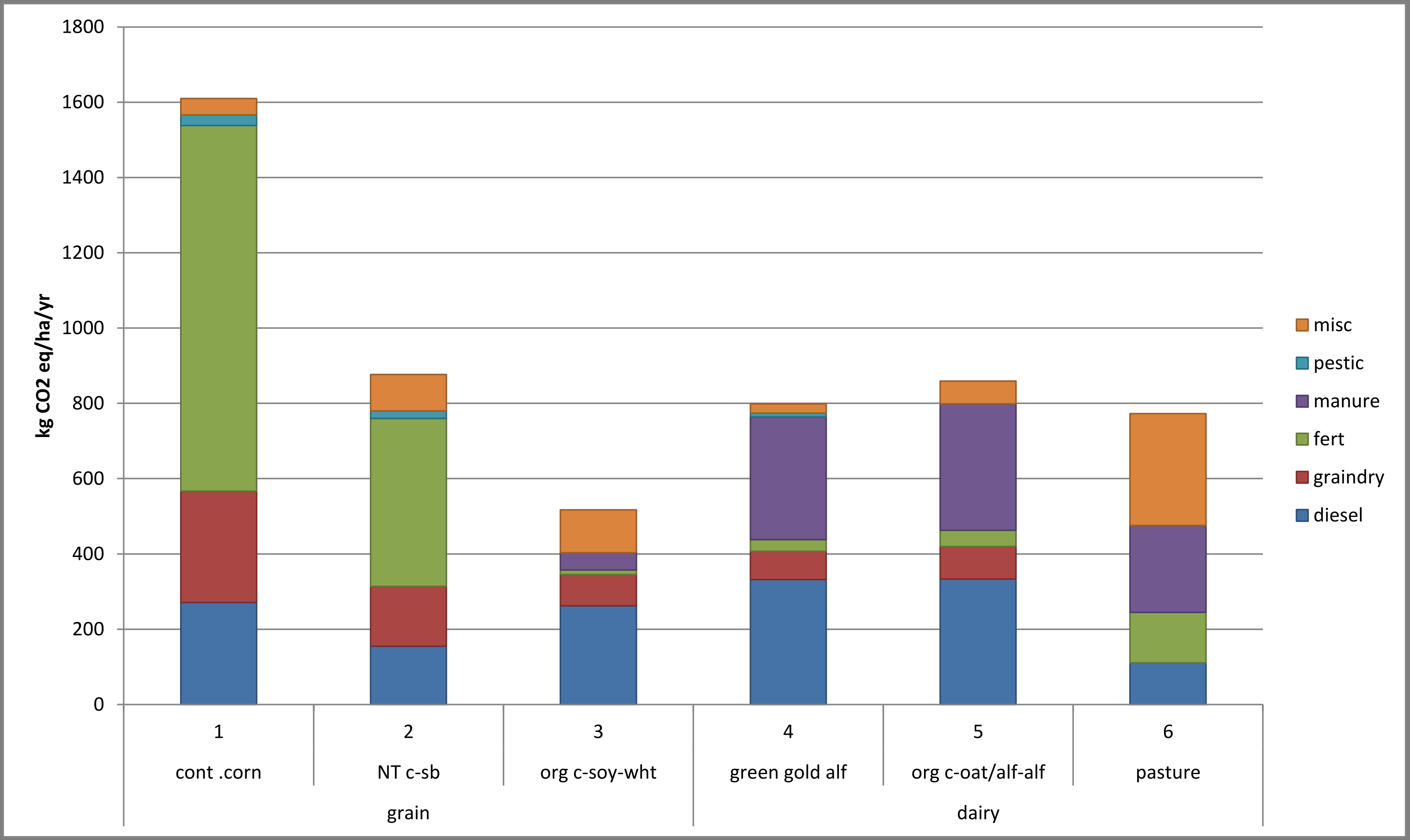
- NT, manure, forage crops – beneficial
- Perennial grasses in crop rotations
  - Grass ley
- Perennial functionality
  - Cover crops, intercropping
- Pasture systems – important part of agricultural landscape

- **Organic Agriculture** trends toward greater use of: manure, forage crops, perennial crops, cover cropping, and intercropping
- Overall reduction of tillage and inputs across systems is beneficial

WICST Life Cycle Analysis

- 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
- N_2O, CH_4, CO_2 computed and converted to CO_2 eq in kg/ha/yr

Embedded components at ARL ($kg\ CO_2$ eq/ha/yr), 1993-2008



Differences of Arid Climates and the Southwest

- Lack of rainfall
- Higher average mean temperatures
- Fallowing practices

How does the WICST data relate to desert southwest?

- Nebraska – compared three winter wheat/fallow management systems
  - no-till management resulted in greatest conservation of soil organic matter and posed the least threat to atmospheric quality relative to loss of greenhouse gases such as CO_2 (Doran, Elliot, and Paustian)

How does this relate to desert southwest?

- Pacific Northwest (Inland Empire) – small grain/fallow systems - summer fallow lost SOM over time without additions of manure
- Most SOM loss was due to high biological oxidation and **absence of C inputs**
- Issue with fallow – **not continually inputting c into the soil**
- Tillage – converting plowing into mulch (non-inversion) tillage conserved N and C
  - **No-till systems** are perhaps the only tillage systems with a chance to maintain SOM at a steady state

Cover Crop Options for NM

- Cowpea-- well acclimated to the desert’s drought and high temperature environment
- Can produce about 2 tons of biomass per acre in 75 days in central Arizona
- Has a favorable C:N ratio and breaks down rapidly
- Iron Clay - common variety
- 20 to 30-inch row spacing at a 35 to 40-pound/acre seeding rate

Cover crop options for desert regions

- Pearl millet - grows 4 feet to 5 feet high and produces 2 to 3 tons of biomass in 60 days
  - planted in June and flowers later in the month
  - has a deep root system that grows well with low nitrogen and water inputs
  - when used in vegetable cropping systems, pearl millet can use residual nitrogen and reduce nitrate leaching
  - recommended planting rate is 5 to 10 pounds per acre
- Other warm-season cover crops with a potential good fit in desert vegetable systems include: lablab; sesbania; sunnhemp; velvet bean; German (foxtail) millet; and Japanese millet

Cover Crop Research in Arizona

- Summer cover crops cowpea and sudangrass can increase yields in soils planted in winter vegetables and spring cantaloupe
- Cowpea planted in July and cut and incorporated into the soil in September; cowpea cut and left on the soil surface as a mulch during the same time frame; sudangrass planted in July and cut in September for soil incorporation; plus a bare ground control plot.
- Incorporated cowpea cover crop improved conventional and organic fall lettuce and spring cantaloupe yields
- Sudangrass cover crop slightly reduced fall lettuce yields, but improved the spring cantaloupe yield

Cover-crop based no-till techniques in NM?

Methods

- Planted cover crops in September
- Cover crops grew through September and October
  - Lablab bean, cowpea, sorghum sudangrass
- Terminated at first killing frost
- Chile transplanted into cover crops in following April

Sorghum sudan before frost

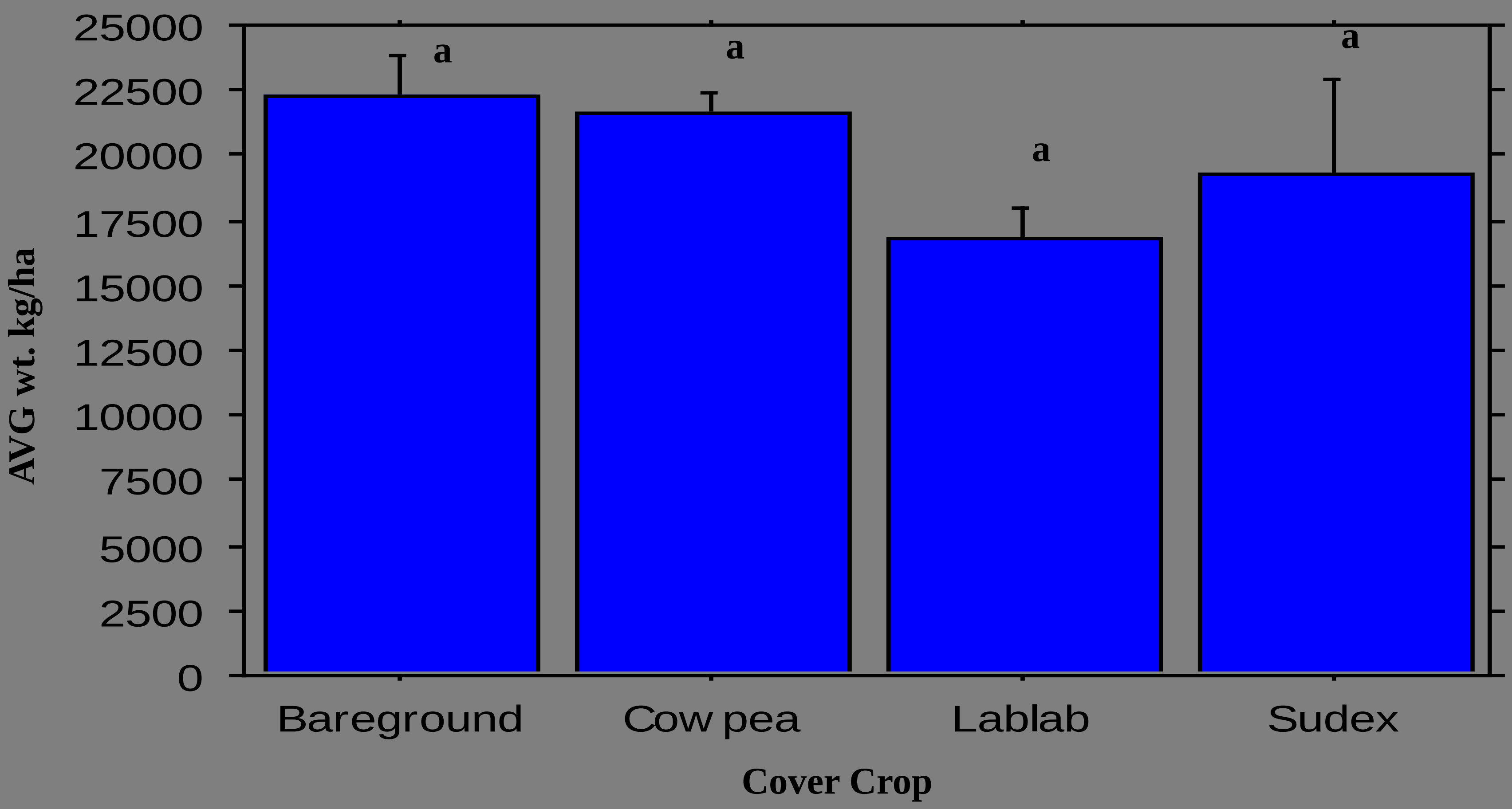
Cowpeas

Killed cover crops

Cowpea

Cowpea and Sorghum Sudangrass

Yield of cold-sensitive cover crops, 2006



*treatment means designated with a similar letter are nonsiginificant at the 5% level

Take-home messages

- Organic production integrates production practices that benefit soil organic carbon
  - Diverse crop rotations – deep rooted crops
  - Compost and manure additions
  - Cover cropping
  - No-Till – cover crop based no-till?
- Maintaining and building soil organic carbon in desert southwest is challenging
- Production strategies that integrate the above approaches will provide best results with respect to building SOC and soil health