GRACEnet

*(**G**reenhouse Gas **R**eduction through the **A**gricultural **C**arbon **E**nhancement network)*

An assessment network of soil carbon sequestration and greenhouse gas mitigation through agricultural management

Presented by: **Ronald Follett**

The Soil-Plant-Nutrient Research Unit
Agricultural Research Service of USDA
Fort Collins, Colorado

SOIL PLANT NUTRIENT RESEARCH
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GRACEnet-Leadership

Ron Follett --- Fort Collins, CO

- Steve DelGrosso --- Fort Collins, CO
- Jane Johnson --- Morris, MN
- Tim Parkin --- Ames, IA
- Jeff Smith --- Pullman, WA

Acknowledgement

- To all GRACEnet scientists for their hard work and creative approaches.
- To those GRACEnet scientists who contributed slides for this presentation.

Why is GRACEnet needed?

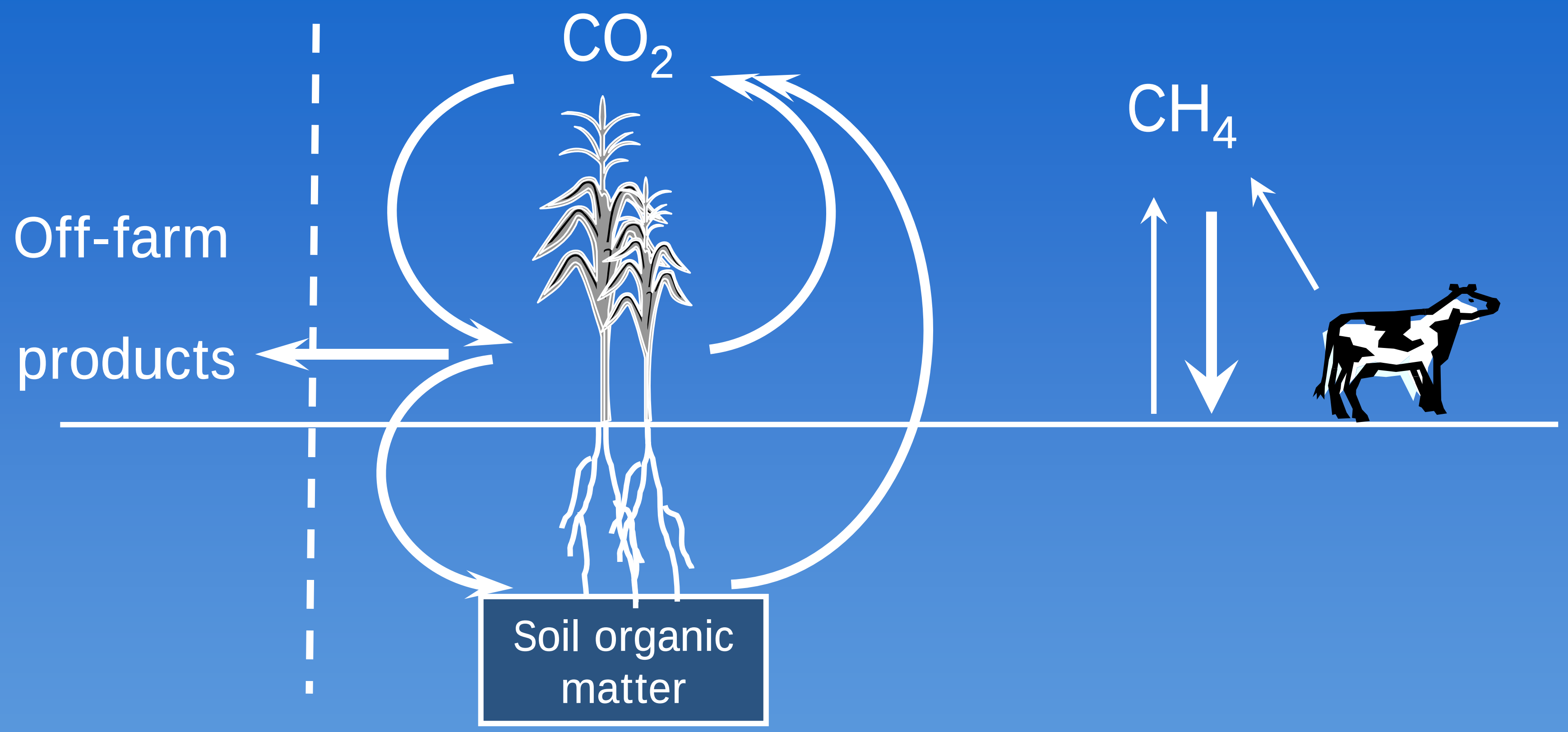
- Observed and predicted climate change is attributed to atmospheric enrichment by greenhouse gases (especially CO_2, N_2O, and $CH_{4.}$).
  - These increases are largely from burning of fossil fuels, land use, livestock husbandry, and cement manufacturing.
  - The atmospheric C pool increased by ~ 3.2 to 3.3 Pg/yr* during the 1980s and 1990s but by 4.1 Pg/yr between 2000 and 2005 (IPCC, 2007).
  - Atmospheric CO_2 has increased from 280 ppm (pre-industrial) to 380 ppm by 2006.

*** 1pg = 10^{15}g = 1,000 MMt = 1,102 MT**

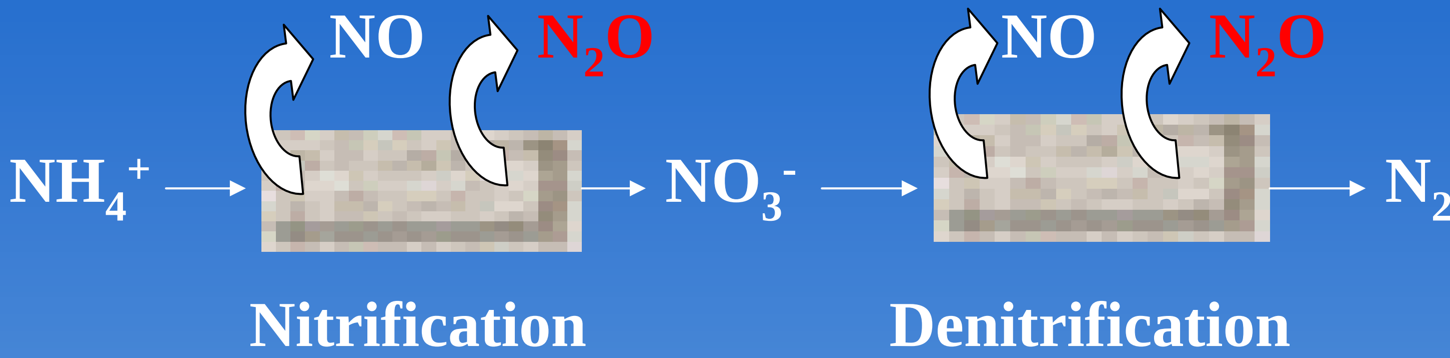
Population Growth

- World population is projected to increase from 6.5 billion in 2007 to 9.5 billion by 2050.
- Increasing populations require energy and plant nutrient inputs to produce the food they need.
- Efficiency per unit input of water, land area, and energy-based input will be of great importance.
- Agriculture is highly important for providing solutions to these urgent issues.

Carbon cycle on agricultural land



Gaseous Emission of N



Conceptual model of regulation of N trace gas production via nitrification and denitrification:

(Firestone and Davidson, 1989)

OBJECTIVES of GRACEnet

1. **Evaluate the soil C status and direction of change of soil C in existing typical and alternative agricultural systems.**

2. **Determine net GHG emission (CO_2, CH_4 and N_2O) of existing and alternative agricultural systems.**

3. **Determine the environmental effects (water, air and soil quality) of new agricultural systems developed to reduce GHG emission and increase soil C storage.**

APPROACH AND PROCEDURES

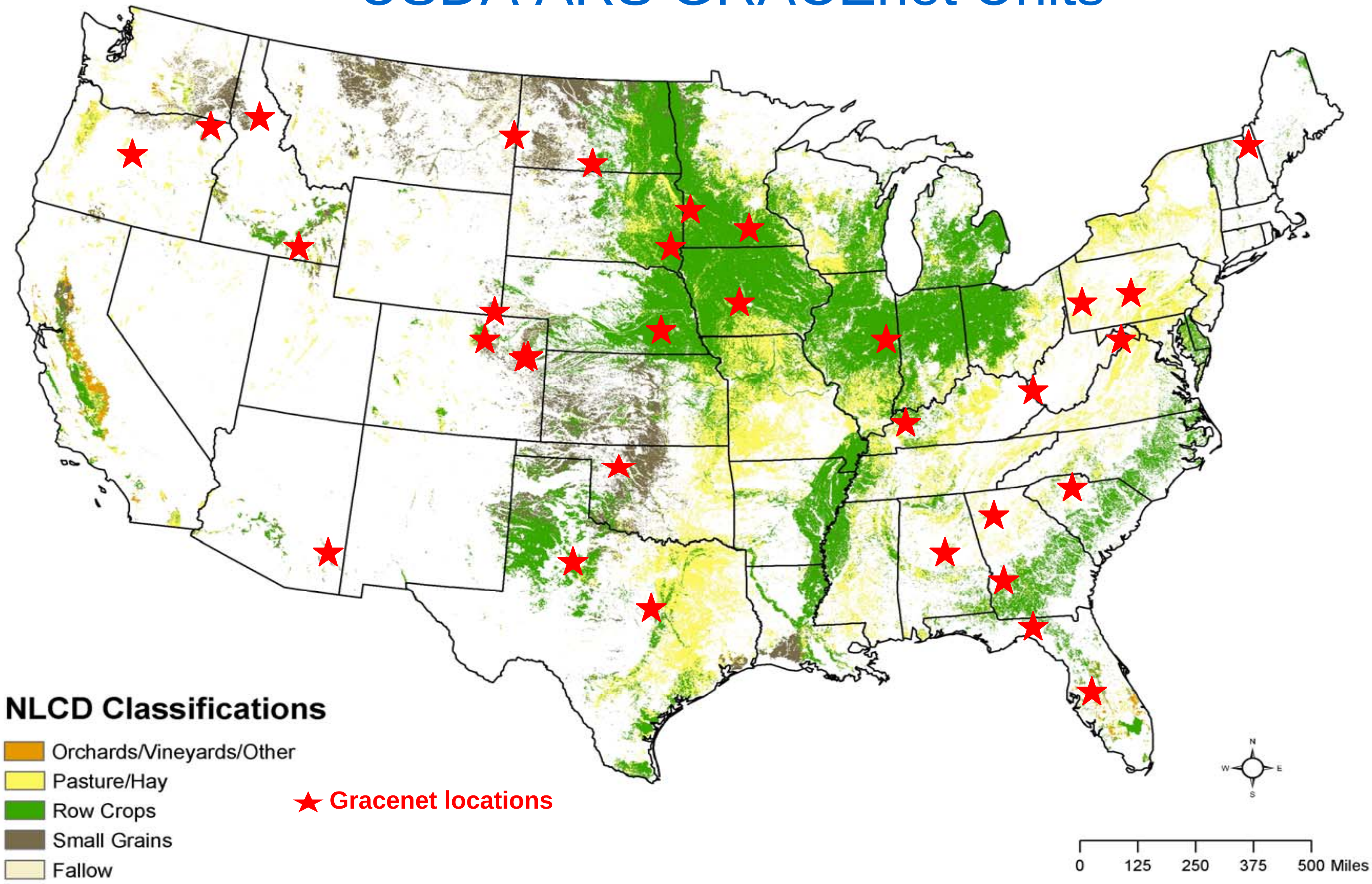
Approach: The GRACEnet experimental concept is based on four location-specific scenarios or treatments:

1. Business as usual
2. Maximizing C sequestration rate
3. Minimizing net GHG emission. This system differs from #2 because N_2O and CH_4 emission must also be considered.
4. Maximizing environmental benefits.

Products:

1. A national database of GHG flux and C storage.
2. Regional and national guidelines of management practices.
3. Development and evaluation of computer models.
4. Summary papers for use by action agencies and policy makers.

USDA ARS GRACEnet Units



What I will cover

- There is way too much material to do justice to, which is good!
- For various GRACEnet locations, I will provide some information about:
  - Experimental resources (land, equip, etc.).
  - Some of the experiments being conducted.
  - Very little about, but some results.

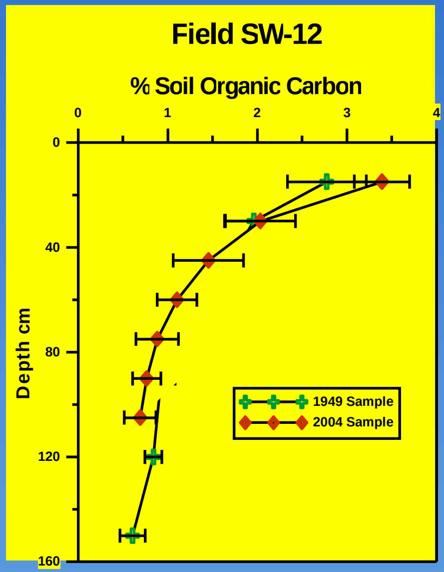
APPROACH AND PROCEDURES

Approach: The GRACEnet experimental concept is based on four location-specific scenarios or treatments:

1. Business as usual
2. **Maximizing C sequestration rate**
3. Minimizing net GHG emission. This system differs from #2 because N_2O and CH_4 emission must also be considered.
4. Maximizing environmental benefits.

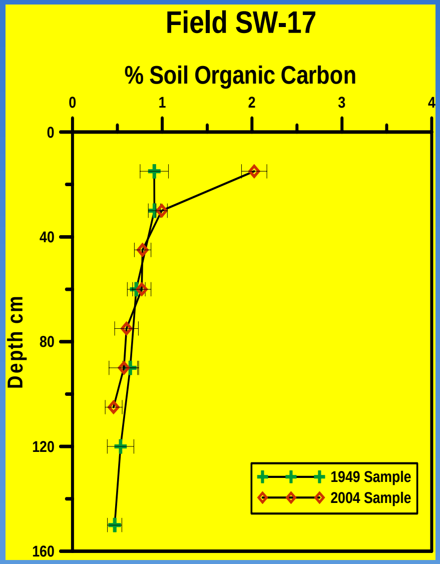
Soil organic carbon contents sampled in 1949 (after intensive conventional tillage in the production fields) and 2004 (with indicated management) in Central Texas. Note that management changed the mass and distribution of carbon, and that modern conventional tillage resulted in a small increase in soil carbon content.

Native pasture



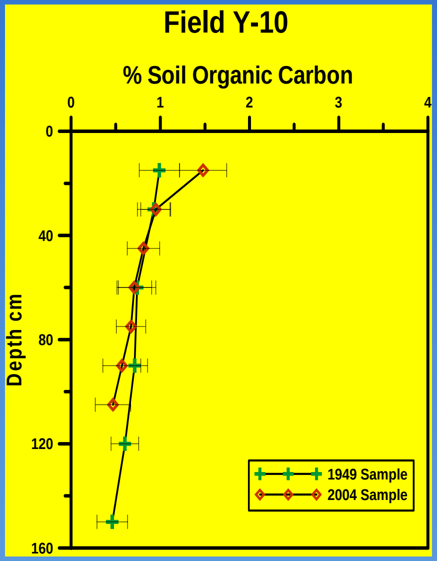
Native Pasture / Meadow

Coastal Bermuda Grass since 1949



•Prior to 1949, Cotton and Corn were the predominate crops
•Sprigged to Coastal Bermuda Grass in 1949

Agricultural production



In row crop and small grain production prior to and after 1949

Soil carbon accumulation and CO_2 flux in a maize, wheat, soybean rotation

A GRACEnet project in the Crop Systems and Global Change Lab, Beltsville, MD

Automated soil CO2 flux chamber

Automated soil CO_2 flux system, spring 2008 (prior to soil preparation for planting)

Results to date

- Tillage affects bulk density, but not yet on soil carbon or crop yield (2 years)
- N affects crop yield (maize and wheat)
- N and tillage affects soil CO_2 flux (spring 2008) (prior to soil preparation for planting)

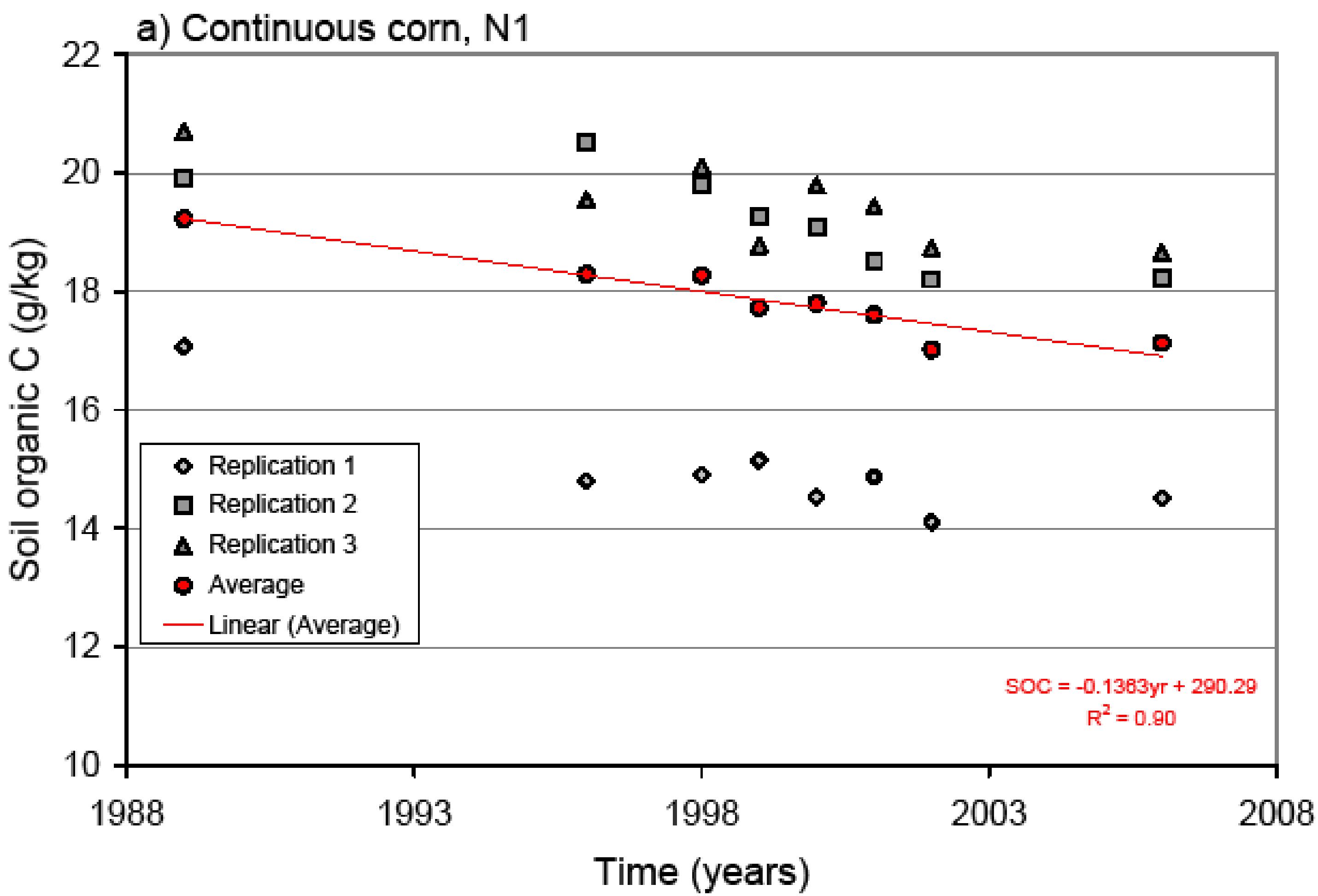
UNIT: North Central Agricultural Research Laboratory (NCARL)
LOCATION: Brookings, SD

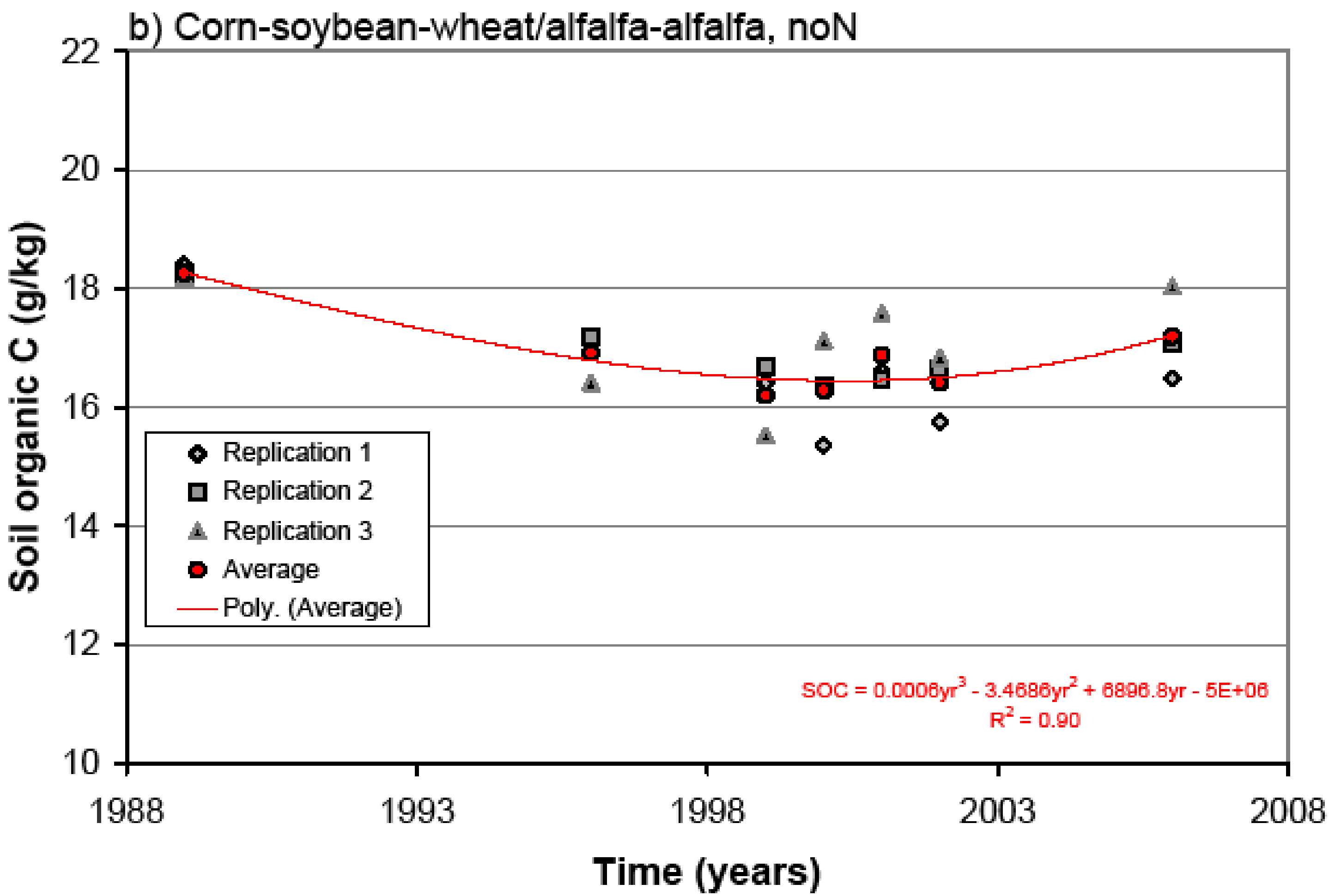
PRIMARY CONTACT:
Mike Lehman, Soil Microbiologist

OTHER SCIENTISTS:
Shannon Osborne, Agronomist
Joe Pikul, Soil Scientist

Location Description

- Upper Mid-West Corn Belt
- Mixed-Grass Prairie
- Mean Annual Temperature 8 °C
- Mean Annual Precipitation, 58 cm
- Barnes Sandy Clay Loam
- All Plots Non-Irrigated


a) Continuous corn, N1
Soil organic C (g/kg)
22
20
18
16
14
12
10
1988
1993
1998
2003
2008
Time (years)
Replication 1
Replication 2
Replication 3
Average
Linear (Average)
SOC = -0.1383yr + 290.29
R^2 = 0.90

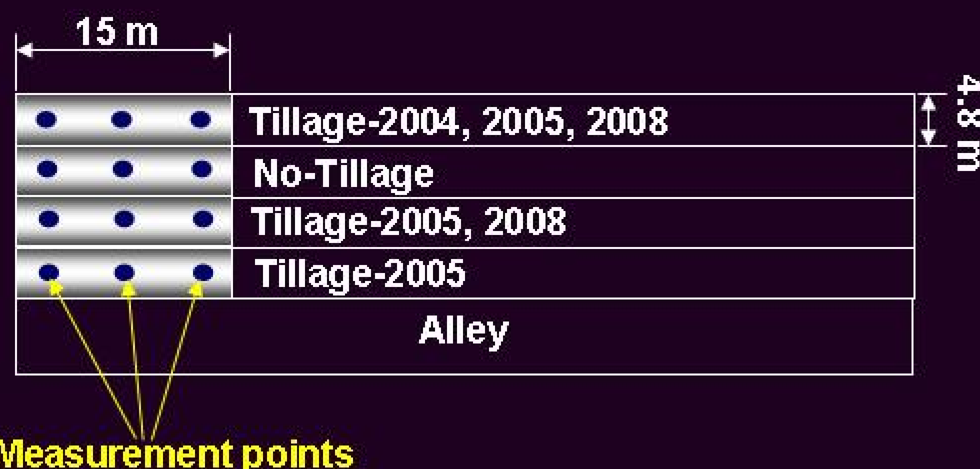

b) Corn-soybean-wheat/alfalfa-alfalfa, noN
Soil organic C (g/kg)
22
20
18
16
14
12
10
1988
1993
1998
2003
2008
Time (years)
Replication 1
Replication 2
Replication 3
Average
Poly. (Average)
SOC = 0.0006yr^3 - 3.4686yr^2 + 6896.8yr - 5E+06
R^2 = 0.90

Central Great Plains Research Station
Akron CO

Primary GRACEnet contact : Maysoon Mikha
Other scientist involved : Merle Vigil

Site Description :

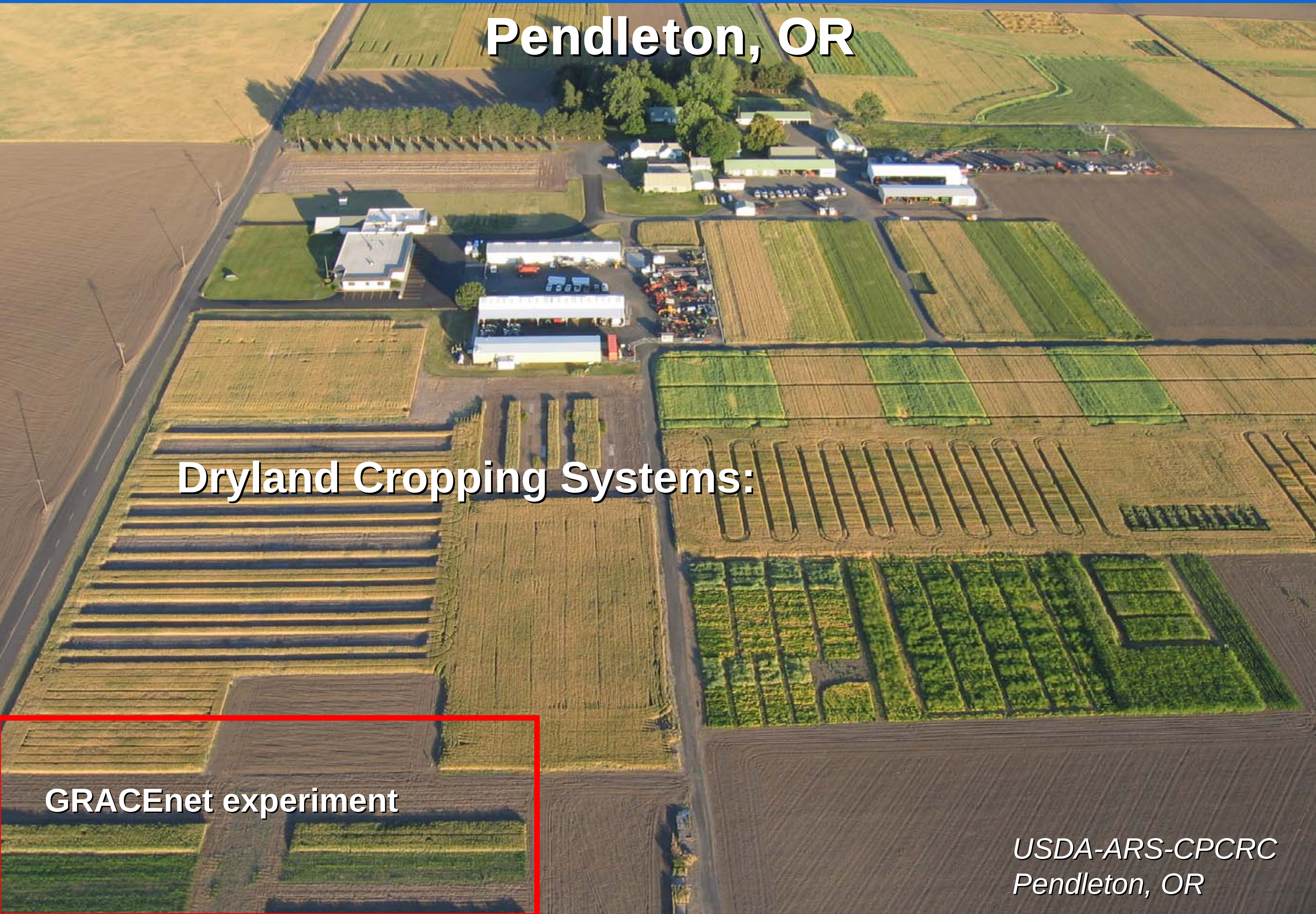
- Long-term no-tillage experiment (Farmer field)
- Treatments: Sweep tillage after 12 years of no-tillage
    - 1 - year tillage
    - 2 - year tillage
    - 3 - year tillage
    - No - tillage



- C Sequestration
    - Soil C
    - CO_2 flux (using Licor)

CO_2 Flux Apparatus

Columbia Plateau Conservation Research Center



Pendleton, OR

Typical cropping system: wheat-fallow, conventional tillage.

- Maximizing C sequestration rate:
  a. Economically viable: wheat-fallow under sweep tillage.
  b. Technically feasible: continuous winter wheat under direct seeding tillage management.

- Minimizing net greenhouse gas emissions: winter wheat-winter wheat-sudan sorghum rotation, direct seeding.

ARS, Sidney, MT

Tillage, Cropping Sequence, and Nitrogen Fertilization Effects on Dryland Soil Carbon Storage and Greenhouse Gas Emission

Primary Contact: Upendra Sainju
Other Scientists Involved: Jay Jabro, Thecan Caesar, and William Stevens

Fig. 1. Tilled and non-tilled malt barley plots (top left) and collection of gas from the static gas chambers (top right). Malt barley at 120 and 0 kg N ha^{-1} (bottom left) and pea and malt barley (bottom right).

Product 2: CO_2 emission

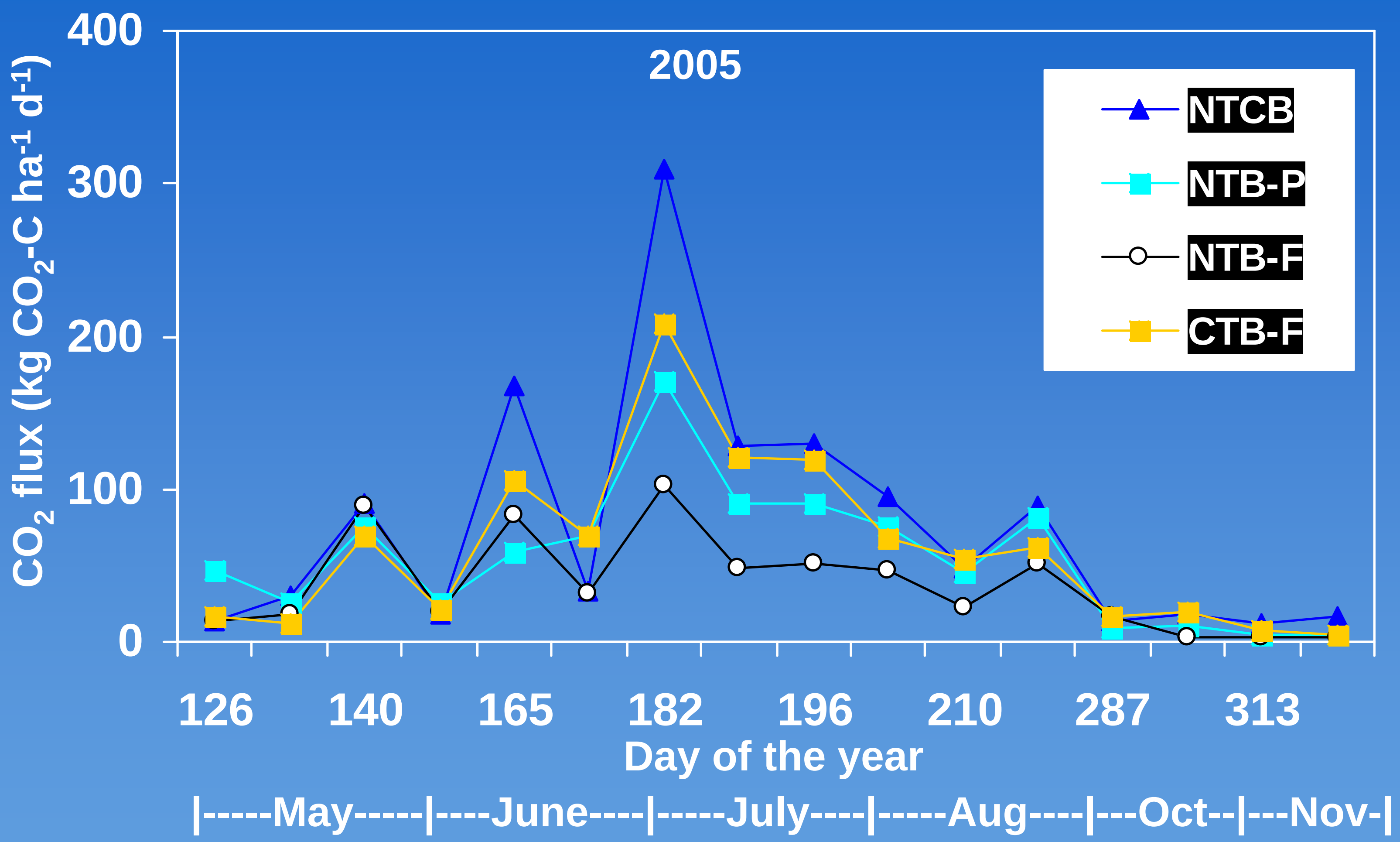
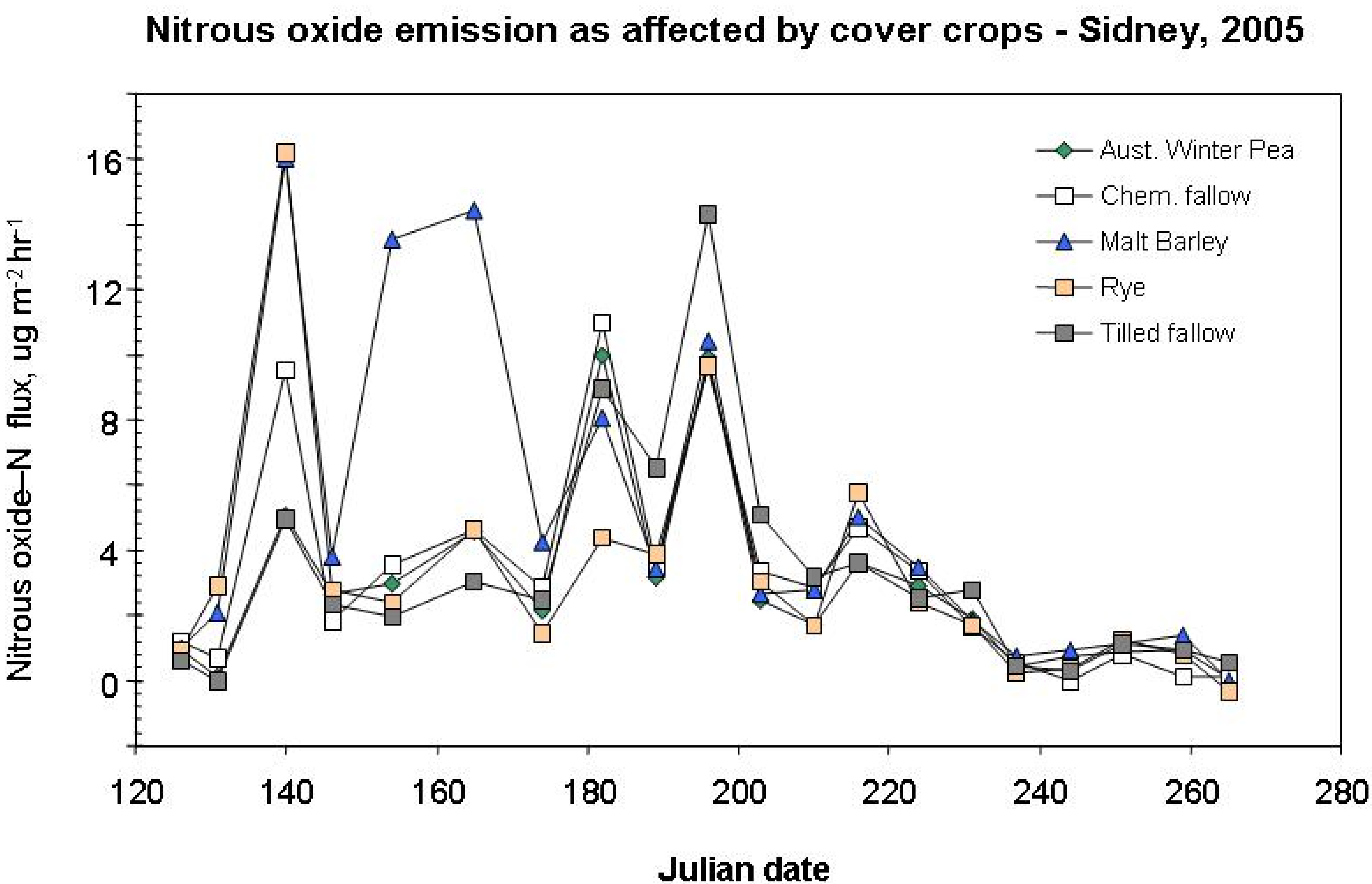


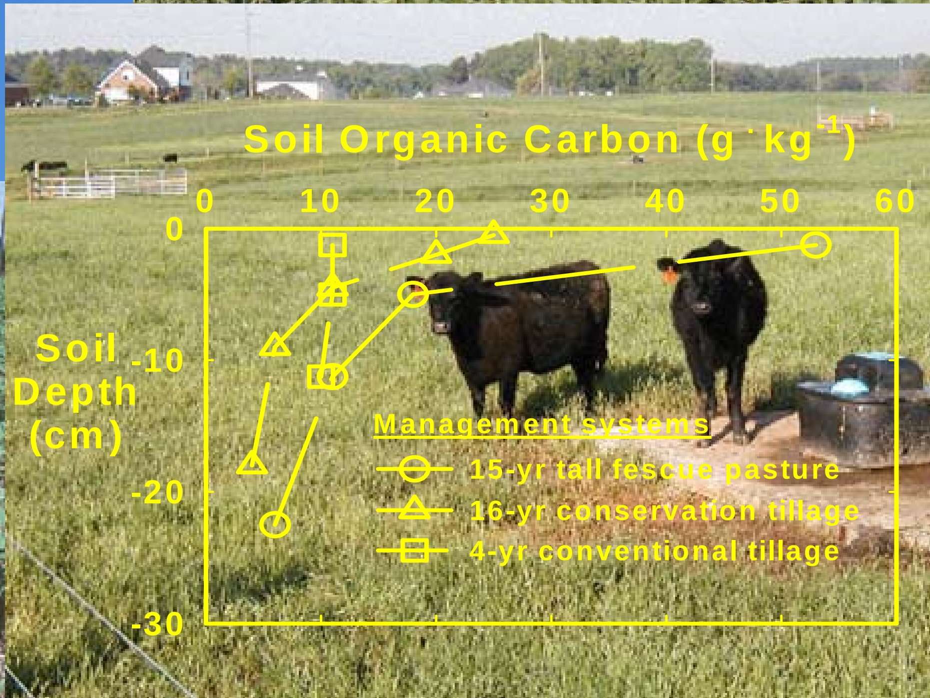
Fig. 2. Carbon dioxide emission as influenced by tillage and cropping sequence in 2005. NTCB represents no-tilled continuous malt barley; NTB-P, no-tilled malt barley-pea; NTB-F, no-tilled malt barley-fallow; and CTB-F, conventional-tilled malt barley-fallow.


Nitrous oxide emission as affected by cover crops - Sidney, 2005
Aust. Winter Pea
Chem. fallow
Malt Barley
Rye
Tilled fallow
Nitrous oxide–N flux, ug m-2 hr-1
Julian date
0
4
8
12
16
120
140
160
180
200
220
240
260
280

GRACEnet – Watkinsville, GA

Database of soil C and trace gas flux for crop, pasture and rangeland systems in the USA.

- Long-term studies of:
- Pasture (nutrient source x endophyte x grazing)
- Cropland (tillage x nutrient source; cover crop management)
- Integrated crop-livestock (tillage x N source x cover crop management)



GRACEnet – Watkinsville

<u>Associated Water Quality Studies</u>

Dawson Field Grazing Study

Pasture-Crop Rotation Study

P 1-4 Watershed Study

Water Quality Plots

RU- Microbial biophysics and residue chemistry
ERRRC, Wyndmoor PA

- Primary: D. Douds
- Others: K. Nichols (ARS Mandan, ND)
- The Rodale Institute:
  - Paul Hepperly
  - Rita Seidel
- Scenarios
  - Conventional
  - Organic, legume cover
  - Organic, manure

Background

- Hypothesis: Mycorrhyzal fungi contribute significantly to carbon sequestration in organically farmed soils.

- Mycorrhyzal fungi produce glomalin, a glycoprotein resistant to degradation
- Relative to the conventional, organic farming systems of the Farming Systems Trial have:
  - Greater populations of Mycorrhyzal fungi
  - More soil C

Influence of pecan-derived biochar on chemical properties of a Norfolk loamy sand soil (Florence, SC)

Jeff Novak[1], Warren Busscher[1], Don Watts[1] and Mohamed Ahmedna[2]
[1]USDA-ARS-CPRC and [2]NC A&T
March, 2008

Increasing SOC contents

- Deep-rooted cover crops (rye, etc.)
- Conservation tillage.

Norfolk soil physico-chemical properties

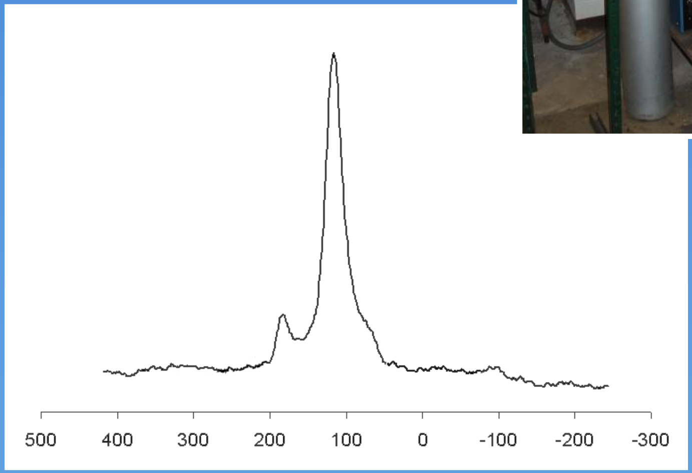
Norfolk loamy sand

- well-drained, marine sediments
- 0 to 15 cm Ap horizon
- underlain by a 15 to 30 cm
- deep E horizon
- E horizon lacks structure and forms
- a hard layer (limits root penetration)

% SOC in Norfolk profile	
Depth (cm)	% SOC
0 to 15	0.39
15 to 30	0.18
30 to 45	0.13
45 to 60	0.14
60 to 75	0.16
70 to 90	0.14

Properties of pecan-derived biochar

- Created biochar from pecan-shells by oxidation to 700°C
- Biochar is 88% OC, 0.4% N (220:1, C:N ratio), pH of 7.5
- Most C (69%) is recalcitrant because it is distributed in polymerized aromatic ring structures



Norfolk soil with and without biochar

Norfolk soil + 0% biochar

Norfolk soil + 1% biochar

Soil C under Improved Grasses on in the Southern Plains Mixed Grass Prairie (Woodward, OK)

1. Compare soil carbon storage in long-term stands of improved grasses to that under the native prairie and cropland.
2. To evaluate plant rooting characteristics and soil C storage in long-term grassland fields.
3. To evaluate above ground biomass productivity of native grasses as potential biomass fuel sources.

Grass species	**Scientific name**	**Origin**	**Estab**	**Years**
Sand Bluestem	*Andropogon hallii* Hack.	Native	1980	28
Switchgrass	*Panicum virgatum* L.	Native	1980	28
Weeping lovegrass	*Eragrostis curvula* (Schrad.)	Introd.	1958	50
Native Prairie		Grazed		100's++
Native Prairie		UnGrazed		50++
Wheat	*Triticum aestivum*	Cropland		28

APPROACH AND PROCEDURES

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4. Maximizing environmental benefits.

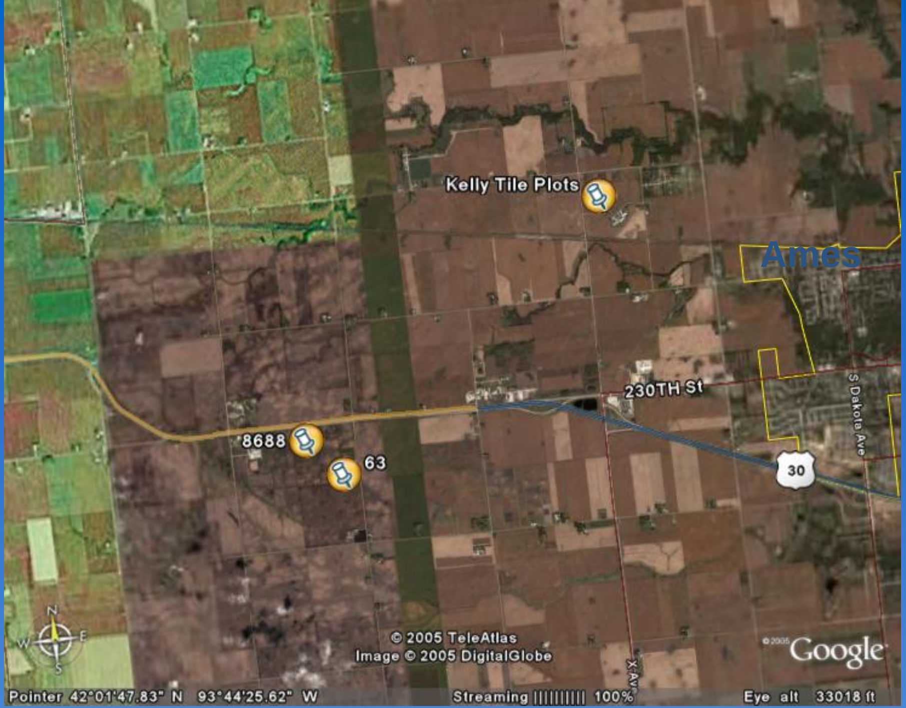
National Soil Tilth Lab

GRACEnet Contact: Tim Parkin

Other Scientists: J.Hatfield, T. Kaspar
J. Prueger, T. Sauer, J. Singer

Site description: Central Iowa
Corn/Soybean

AMES, IA



Methods

Soil Sampling: April

First Year : 0-90 cm

Subsequent Years: 0-30 cm

Variables: O.C, T.C, T.N., E.C., pH, NO3, NH4, W.C.,Texture

Plant Sampling:

October: Yield, Above Ground Biomass

April: Surface Residue

Trace Gas: N_2O, CH_4

-2 chambers/plot (in- and between rows)

-March through Sept. 1x / week

-Oct. through Dec. 2x / week

-Jan., Feb., 1x / month

-30 cm diameter vented chambers

-Gas samples at 0, 15, 30, and 45 minutes

Ancillary measurements:

-soil water content (0-6cm)

-temperature (air, 5 cm)

-Data loggers – temperature: air, 5, 10 cm (hourly).

Other Studies

Temporal variability of N_2O emissions using automated chambers

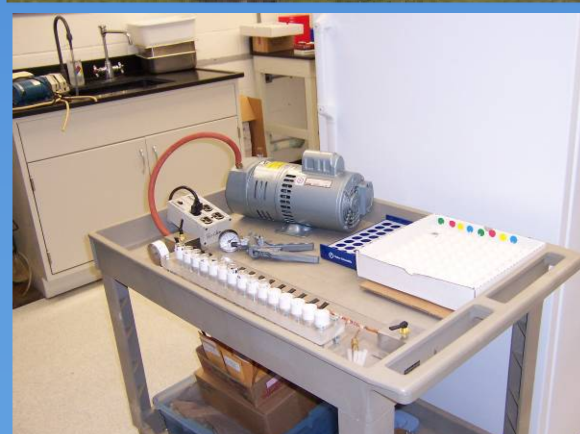
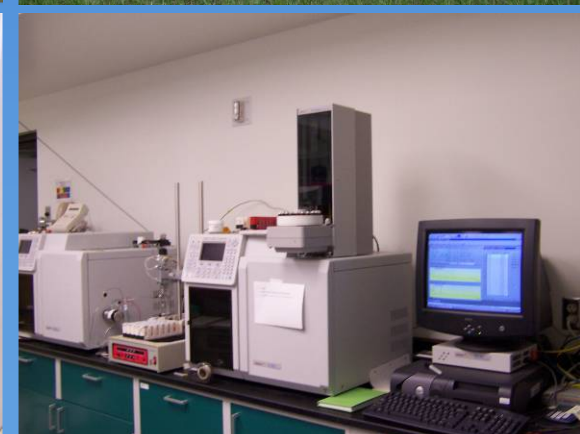
Annual C balance in corn/soybean fields using eddy covariance


Primary contact: Jane Johnson;
Others: Don Reicosky, Sharon Weyers
Morris, MN
North Central Soil Conservation
Research Laboratory







Manure and tillage effects on carbon loss and water fluxes using eddy covariance techniques

D. C. Reicosky[1], J. M. Baker[2], T. E. Ochsner[2], S. Lachnicht Weyers[1]

[1] USDA-ARS, North Central Soil Conservation Research Laboratory,
803 Iowa Ave., Morris, MN 56267; Phone: 320-589-3411, ext. 144;
E-mail: don.reicosky@ars.usda.gov
[2] USDA-ARS and University of Minnesota, St. Paul, MN

Nitrogen Fertilization Effects on Nitrous Oxide Emissions from Irrigated Cropping Systems
Fort Collins, CO

Ardell D. Halvorson, Soil Scientist

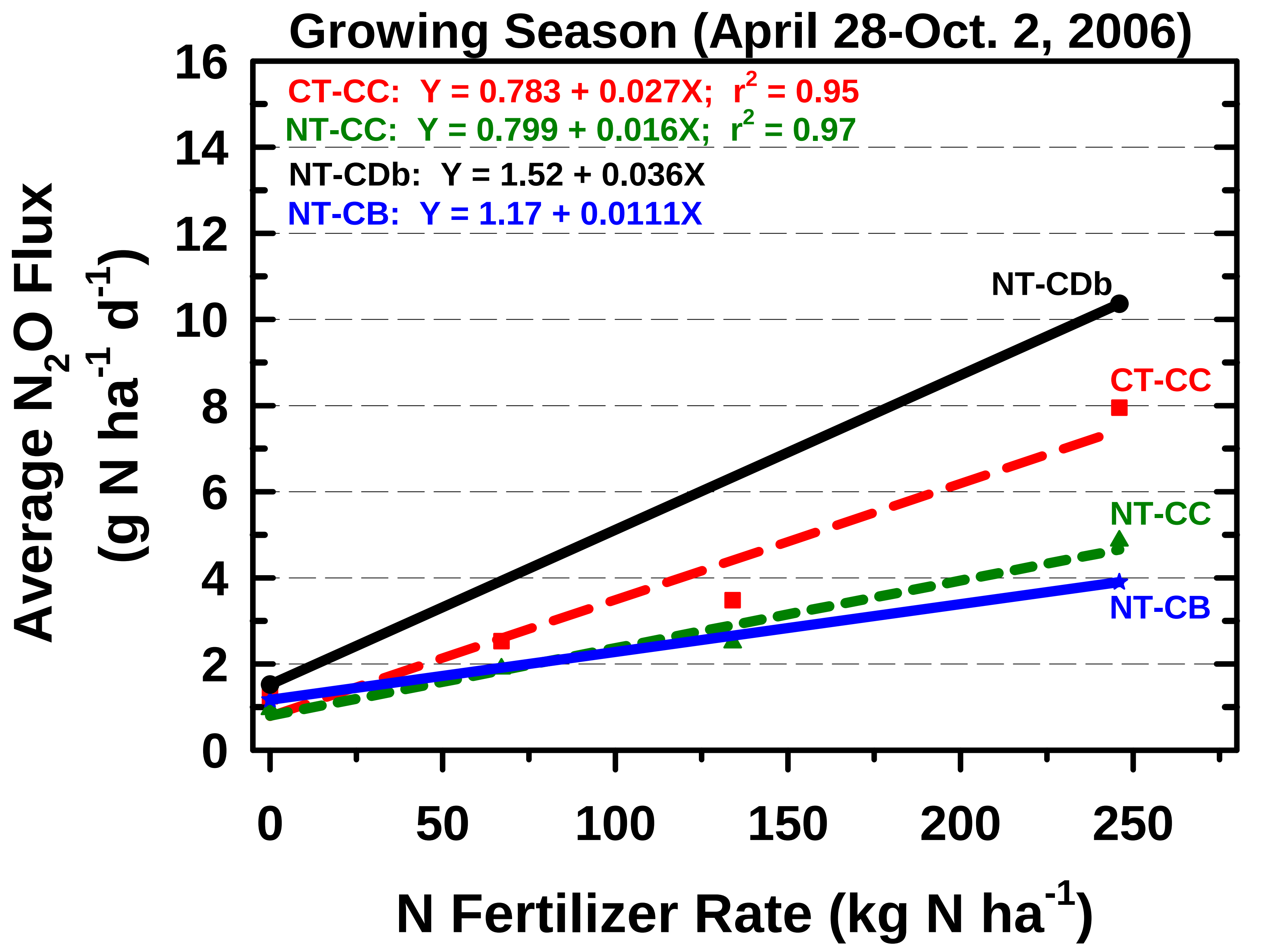
Steve Del Grosso, Soil Scientist

Curtis A. Reule, Soil Scientist

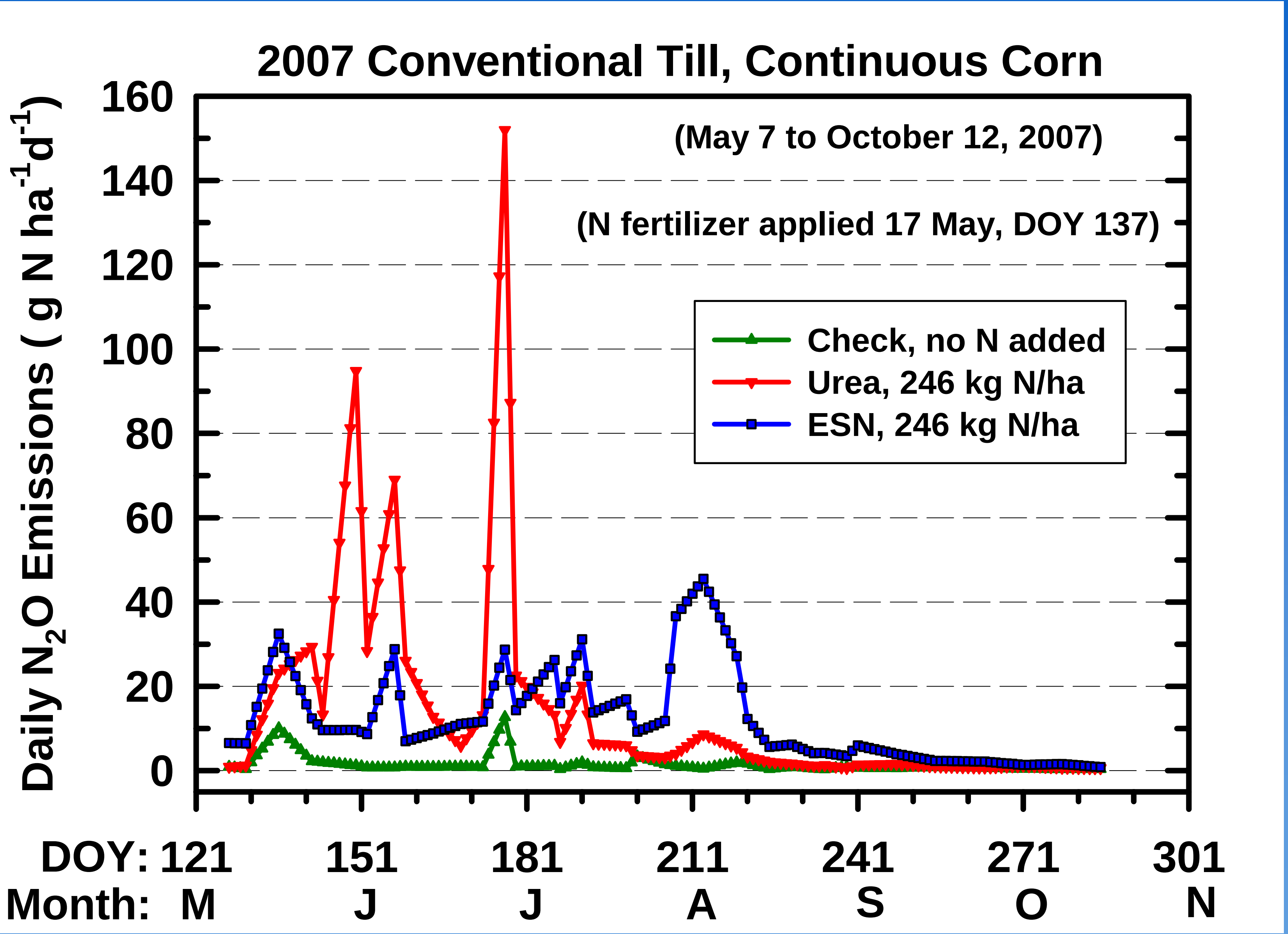
USDA-ARS, Fort Collins, CO

Email: ardell.halvorson@ars.usda.gov


Conventional Till
No Till



Growing Season (April 28-Oct. 2, 2006)
CT-CC: Y = 0.783 + 0.027X; r2 = 0.95
NT-CC: Y = 0.799 + 0.016X; r2 = 0.97
NT-CDb: Y = 1.52 + 0.036X
NT-CB: Y = 1.17 + 0.0111X
NT-CDb
CT-CC
NT-CC
NT-CB
Average N2O Flux (g N ha-1 d-1)
0
2
4
6
8
10
12
14
16
0
50
100
150
200
250
N Fertilizer Rate (kg N ha-1)


2007 Conventional Till, Continuous Corn
(May 7 to October 12, 2007)
(N fertilizer applied 17 May, DOY 137)
Check, no N added
Urea, 246 kg N/ha
ESN, 246 kg N/ha
Daily N2O Emissions (g N ha-1d-1)
160
140
120
100
80
60
40
20
0
DOY: 121
151
181
211
241
271
301
Month: M
J
J
A
S
O
N

St. Paul, MN

Site description: Glacial Outwash Plain. Silt loam soil

- Primary land use in the region : Corn/soybeans

John Baker, ARS

Rod Venterea, ARS

Tyson Ochsner, ARS

Tim Griffis, U of M collaborator

R3 plots

Chamber measurements of N_2O, CH_4, & CO_2 fluxes

Also soil temperatures and water contents, yield, NO_3 leaching

Field-ScaleTreatments

Eddy covariance measurements of CO_2 exchange, ET
Also soil water & heat flow, some C isotope research

1. **Business as usual** – Corn/soybeans, chisel/disk tillage

2. **C sequestering** – Minimum tillage, rye cover crop after corn

3. **Optimized for total env. Benefit** –corn / kura clover

Production System affects soil C stocks and physical properties (**Orono, Maine**)

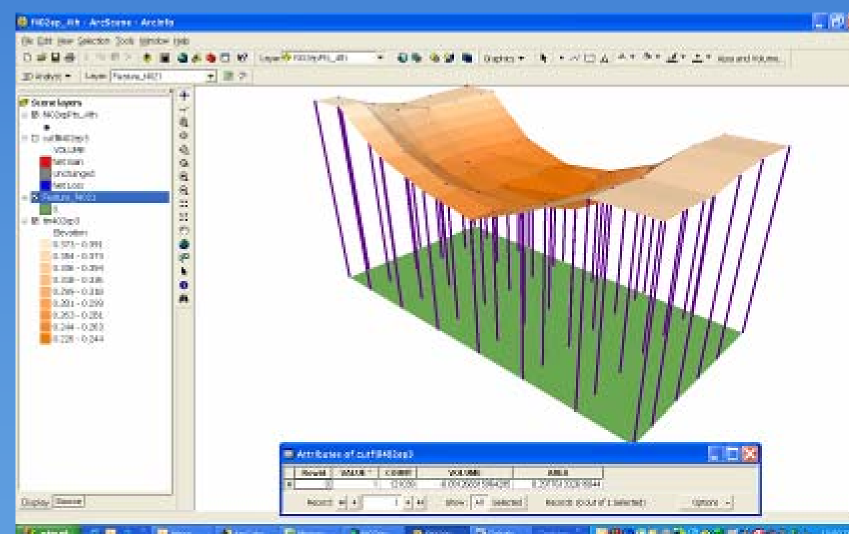
	Soil C	POM-C	Stable Aggregates
	%	% of C	0.5 - 2 mm
Barley-Potato	2.43	19.8	54
Soil Conserving	2.34	21.4	60
Soil Improving	3.18	34.7	62

Experiment started in 2004, soil samples from May 2007

Chamber in Barley

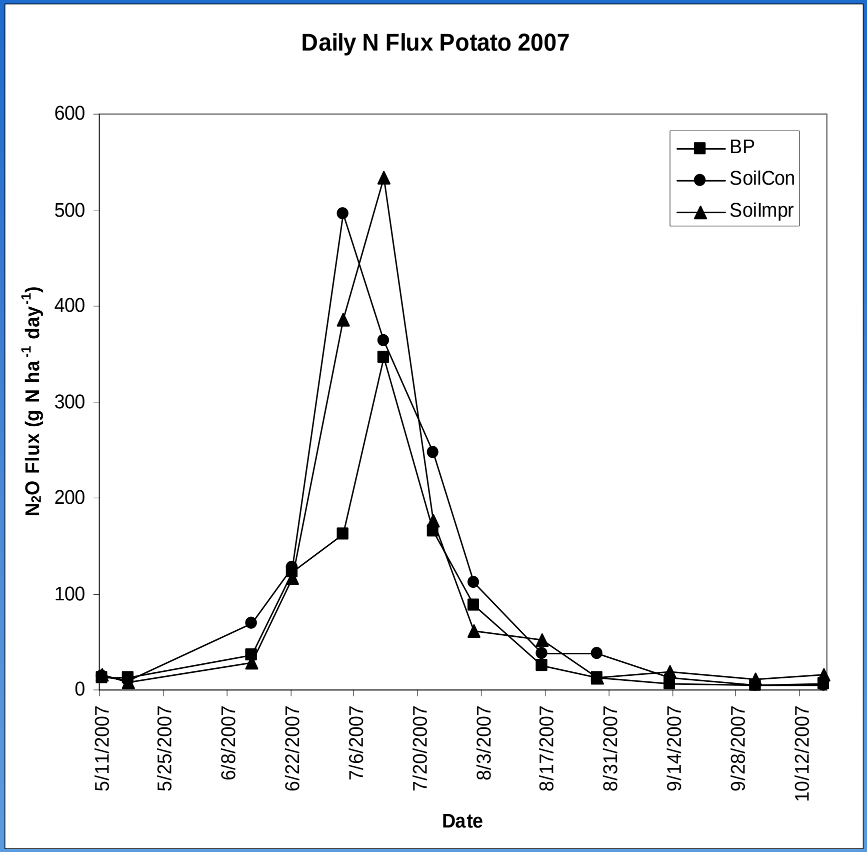
Chamber in Potato

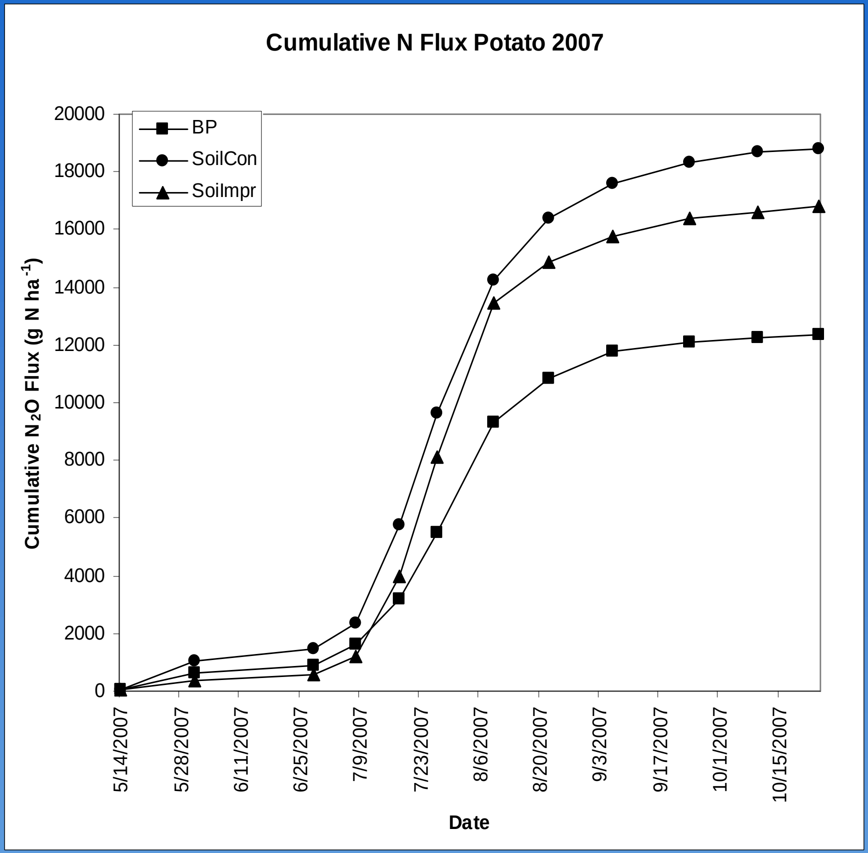
Micro-topography



Headspace Estimation

N_2O from potato – Presque Isle ME





BP = 2-yr Barley-Potato rotation
SoilCon = 3-yr Barley-Sod-Potato rotation
SoilImp = 3-yr Barley-Sod-Potato rotation, with compost each year

UNIT: North Central Agricultural Research Laboratory (NCARL)
LOCATION: Brookings, SD

PRIMARY CONTACT:

Mike Lehman, Soil Microbiologist

OTHER SCIENTISTS:

Shannon Osborne, Agronomist

Joe Pikul, Soil Scientist

Site 2: Long-term Alternative Rotations

GRACEnet Objective: net GHG emissions

GRACEnet Measures: CO_2, CH_4, N_2O

- ✓ **Established 2000**
- ✓ **ten 4-yr rotations, each phase**
- ✓ **4 reps each, random block**

GRACEnet Treatments:

- ❑ Business as usual: corn/soy
- ❑ Env. benefit: corn/pea/ww/soy; corn/oats/ww/soy

CO_2 Flux (mg CO_2-C/$m^2 \cdot h$)

- Summer: 40 – 160
- Fall: 10 - 20
- Winter: <10
- Spring: up to 100 at planting

N_2O flux

- generally neutral
- spring positive flux

Methane flux

- slight sink

GRACEnet Location Synopsis
Northern Great Plains Research Laboratory
Mandan, ND

Mark Liebig, Rebecca Phillips, David Archer,
Scott Kronberg, Jason Gross

May 2008

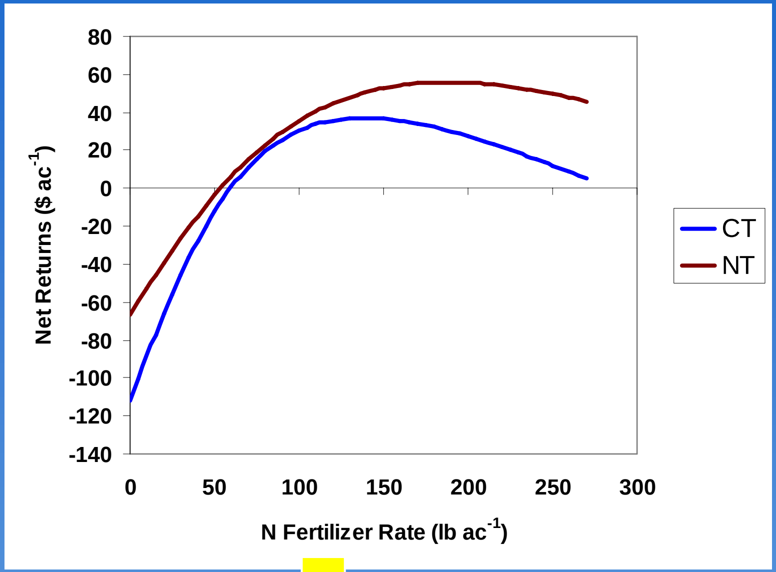
NGPRL

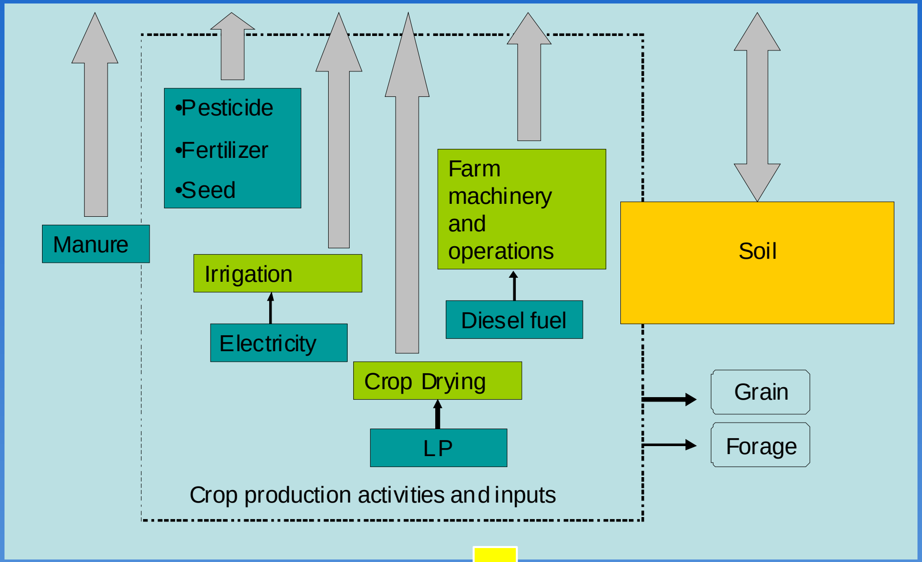
USDA Agricultural Research Service

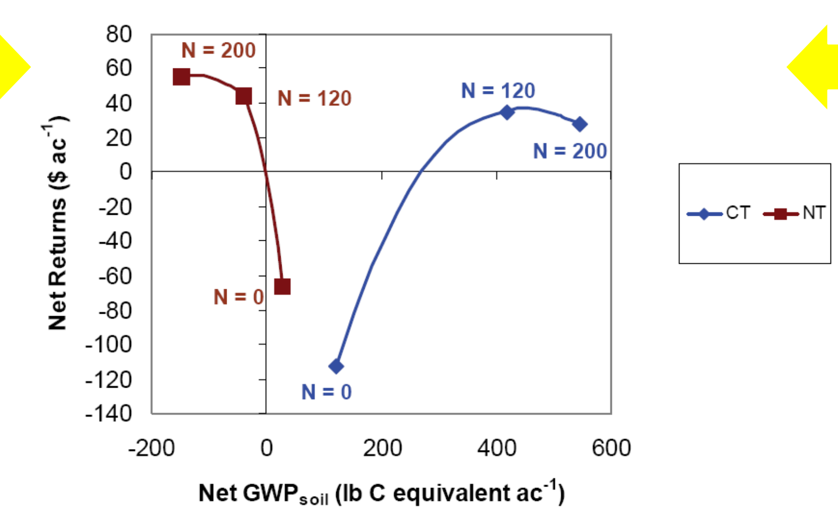
Field Evaluations (GHG flux, SOC)
NGPRL (Liebig, Phillips, Gross, Kronberg)

- Long-term grazing and cropping systems (Liebig, Gross)
- N_2O emissions from late-autumn manure application to cropland (Phillips)
- Hydropedologic vegetation zones in wetland landscapes (Phillips)
- N_2O emissions as influenced by Tannin-affected cattle urine (Liebig, Kronberg)

Economic / Life-cycle Analysis
NGPRL (Archer)







Greenhouse Gas Emissions following Application of Swine Effluent by Different Methods
Bowling Green, KY

- **Research conducted at Animal Waste Management research Unit**
  - **Karamat Sistani and Jason Warren**

Objective:

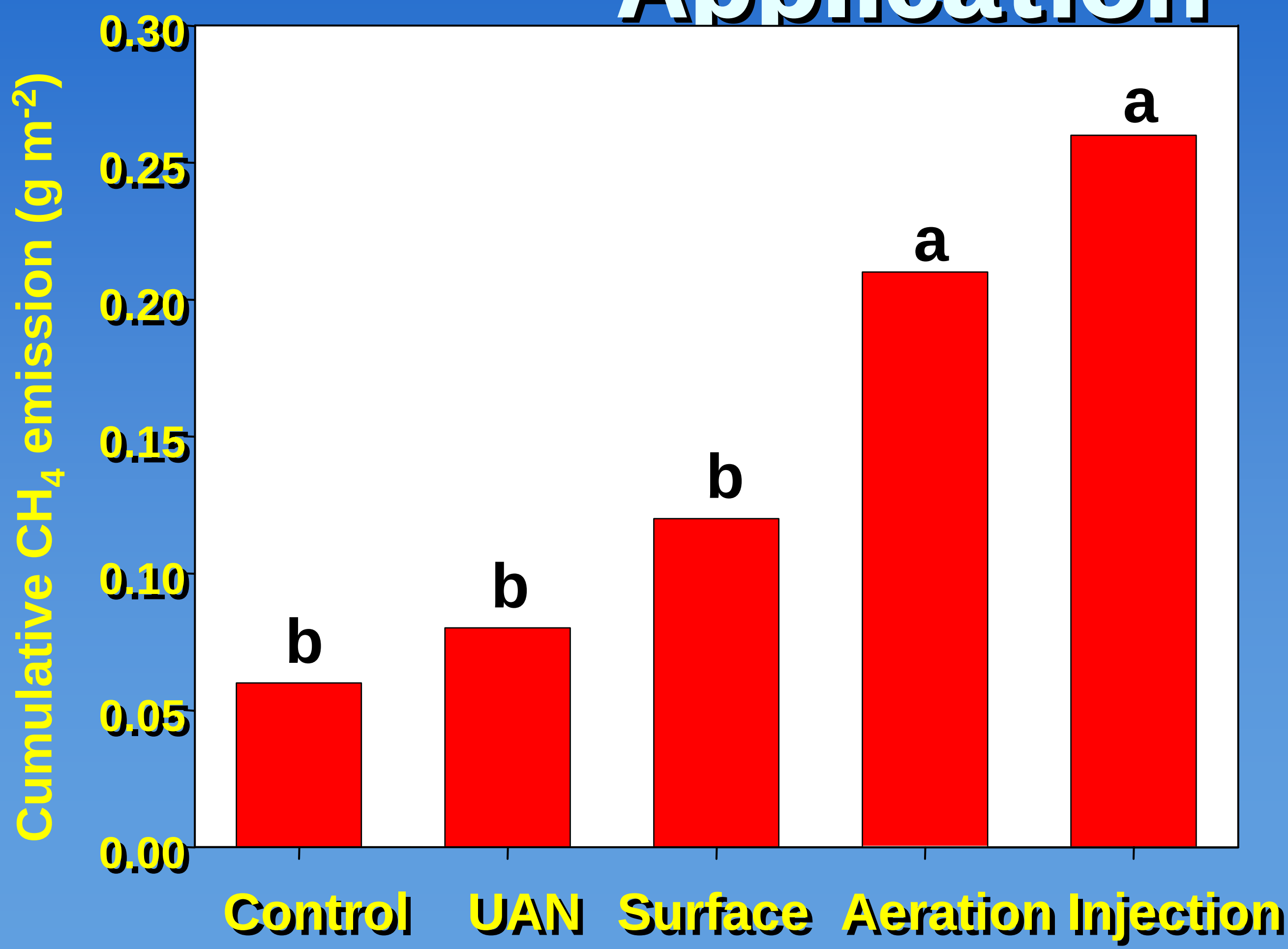
- **Evaluate greenhouse gas emissions from swine effluent after injection, surface application or application in combination with aeration in a no-till corn grain production system.**


Injection


Surface application

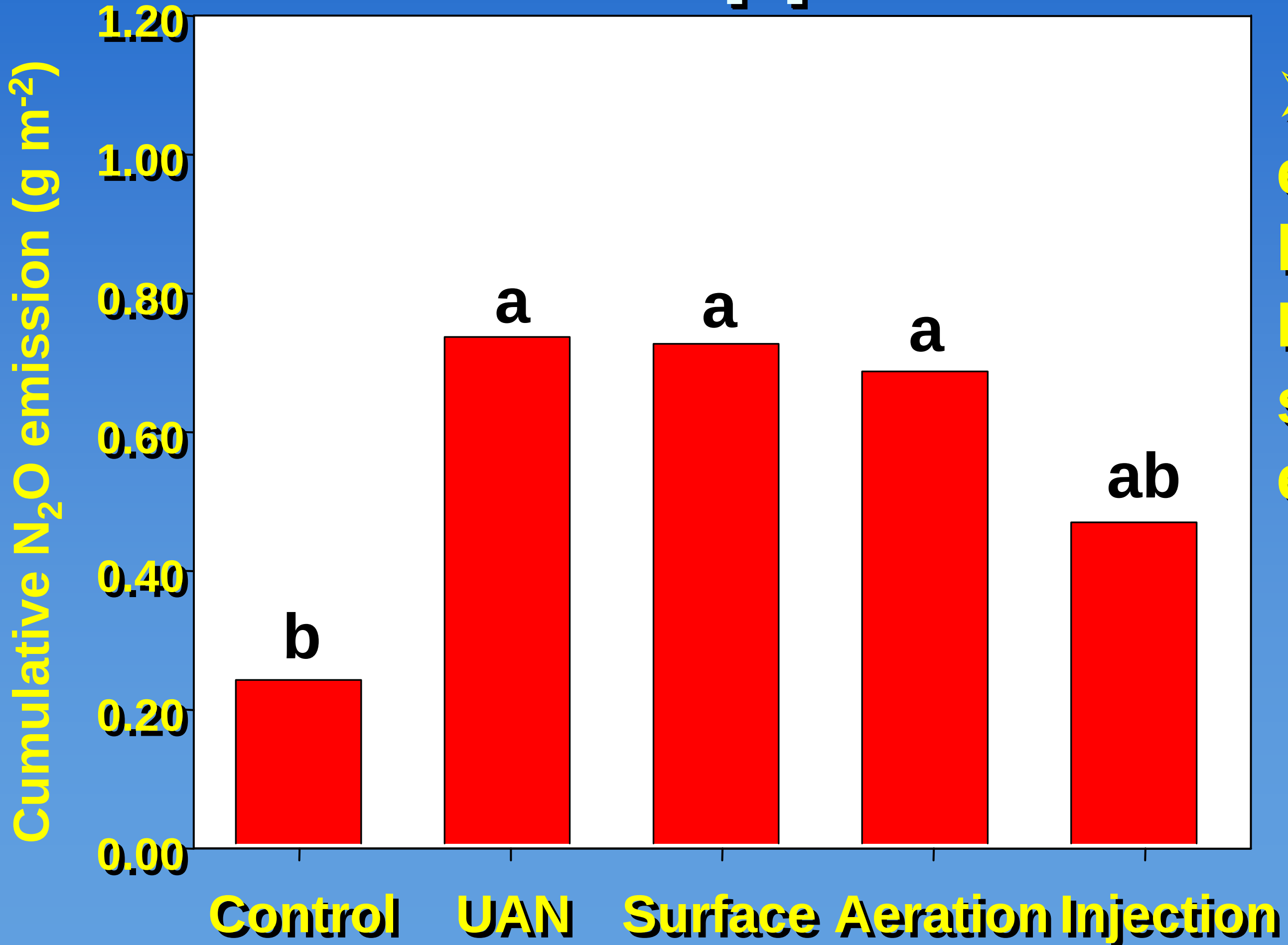

Aeration

Cumulative CH_4 Emissions during 141 Days after Application



- Incorporation appears to promote CH_4 emissions
- CH_4 emission from effluent incorporation was elevated for approximate 7 Days after application.

Cumulative N_2O Emissions during 141 Days after Application



- Injection of swine effluent appears to limit the amount of N_2O emitted from soil applied swine effluent

Southwestern Rangelands and Greenhouse Gas (Tucson & Maricopa, AZ)

- Southwestern rangeland soils, despite arid soil conditions, cycle vast amounts of trace gases.

- Such rangelands cover more than 200 million ha of land area in the Western US.

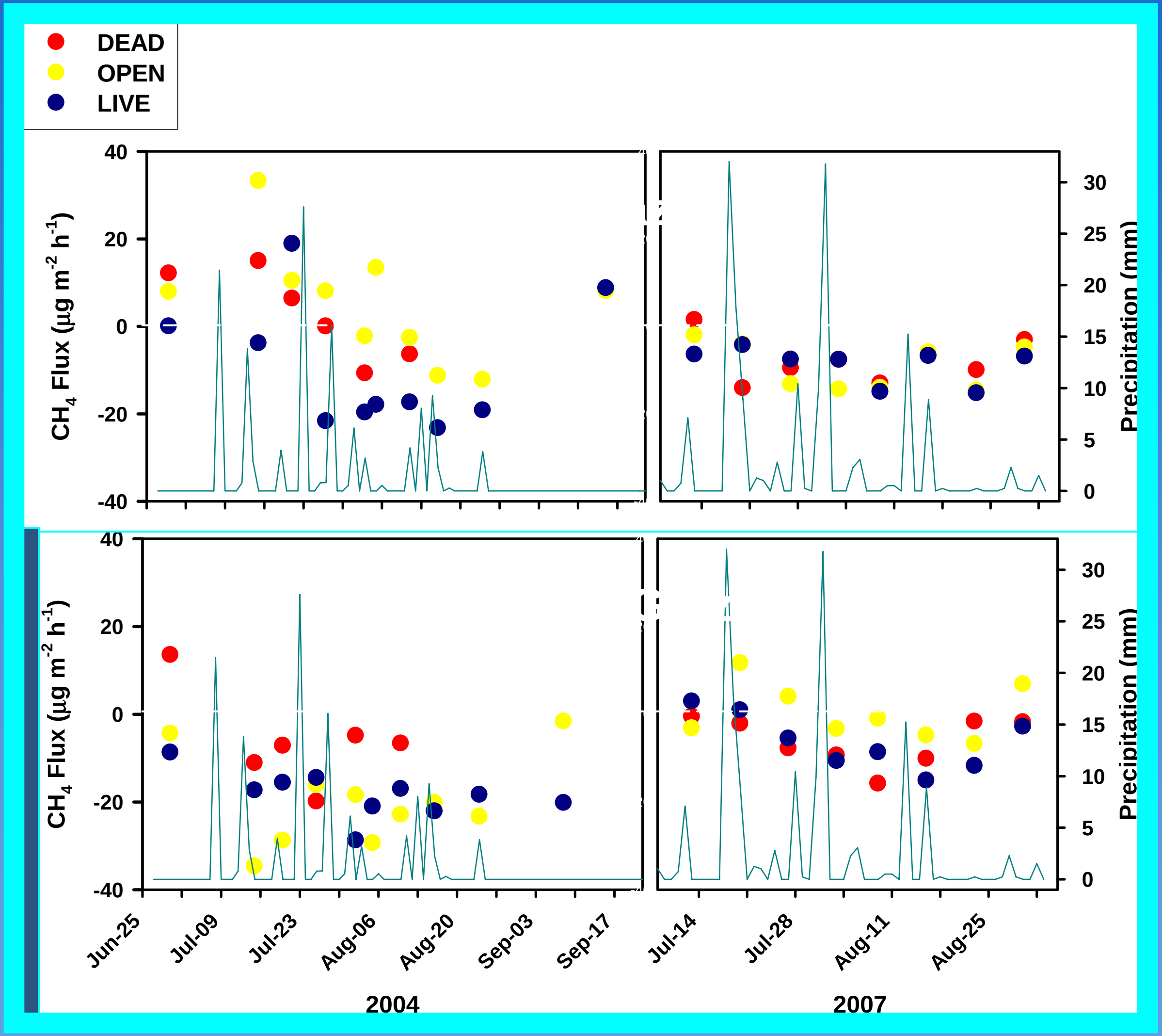
- Summer 2004 and 2007: Explored CH_4 dynamics in response to cattle grazing and mesquite control

Live Mesquite

Dead Mesquite

Open Site

Results: CH_4 Surface Flux



- Early monsoon CH_4 production in all sites.
- Non-grazed sites (bottom) consumed CH_4 at a 2X the rate of the grazed sites (top).
- The strongest contributors to the CH_4 sink were the living mesquite sites.

Effects of Elevated Atmospheric CO_2 on Agriculture (Auburn, AL)

- Pasture Systems of the Southeast
- Conventional vs. Conservation Cropping System

Results

- **Soil CO_2 efflux increased by both elevated CO_2 and conservation management**
- **In both cases, soil CO_2 efflux increased by approximately 50 %**

Development of a Subsurface Applicator for Poultry Litter

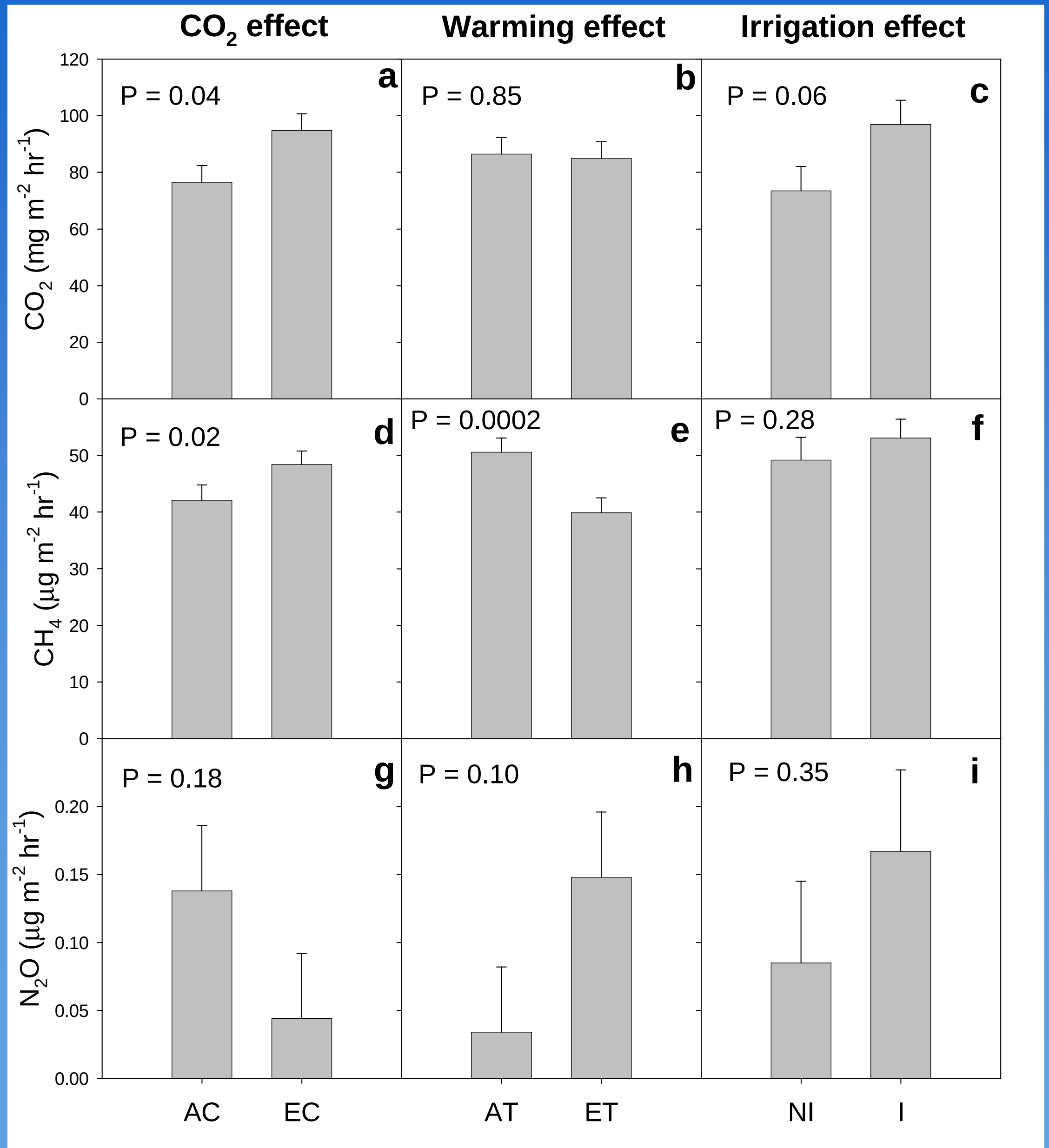
Alabama
Arkansas
Kentucky
Maryland
Mississippi

Prairie Heating And CO_2 Enrichment (PHACE) – Cheyenne, WY

- Semi-arid rangeland system
  - Annual precip: 388 mm
- CO_2 treatment: ambient vs 600 ppm
- Warming treatment: day: +1.5 °C during the day and +3 °C during the night
- Irrigation treatment: three irrigations during the growing season, 20 mm each

Photo: Elizabeth Pruessner

CO_2 production and CH_4 consumption increases with elevated CO_2. CH_4 consumption decreases with warming.

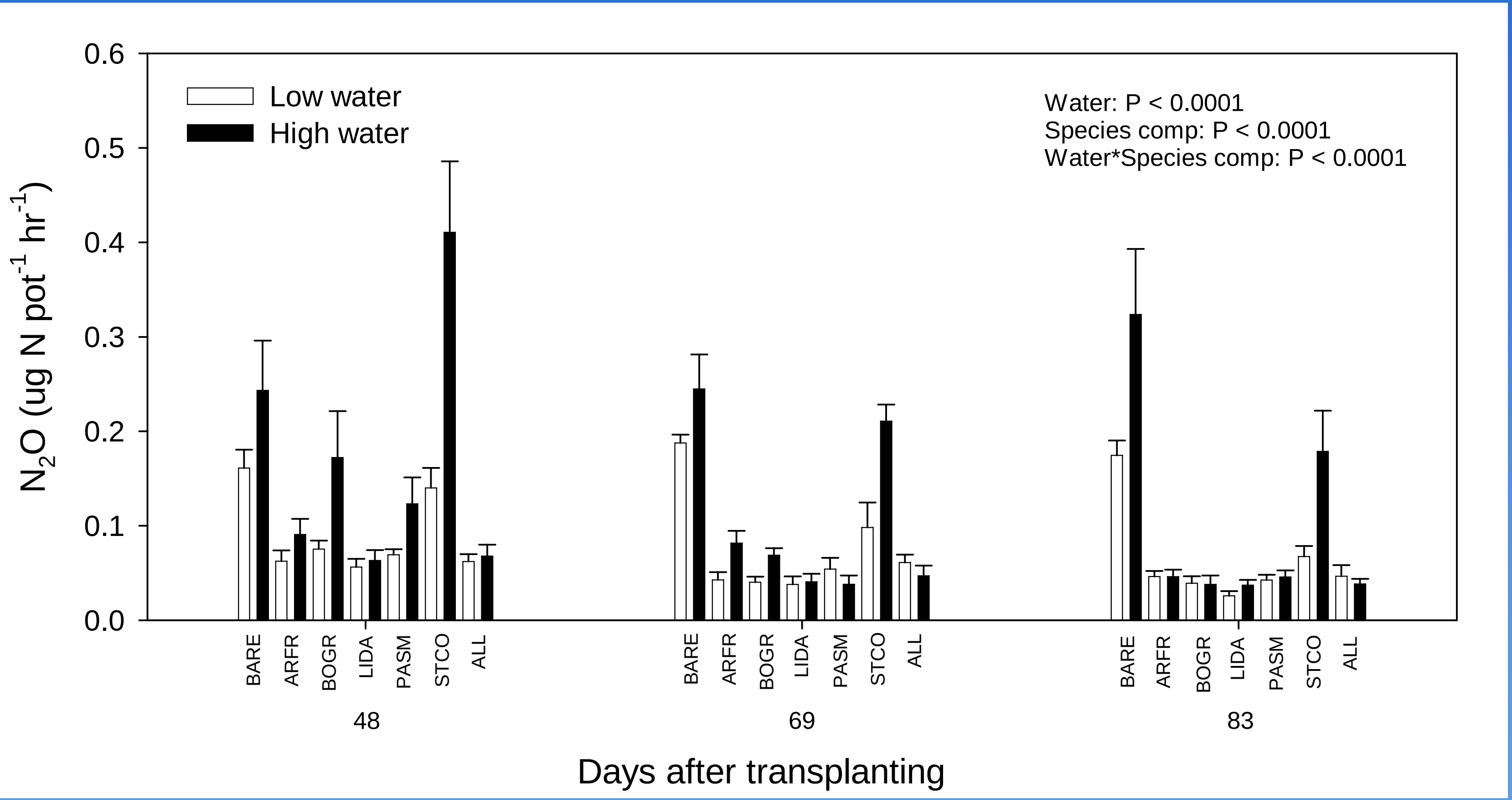


CO_2, water, and species composition effects on greenhouse gas fluxes – a greenhouse study of the effect of:

- Atmospheric CO_2 (380 vs. 750 ppm)
- Water availability (15 vs. 20%)
- Species composition: no plants, perennial grasses *Bouteloua gracilis*, *Pascopyrum smithii*, *Stipa comata*, the sub-shrub *Artemisia frigida*, and the forb *Linaria dalmaticai*, and all five together.


88
Good

N_2O production significantly differed among species and interacted with water availability



University Park, PA

- Greenhouse gas emissions and C sequestration from:
  - **Dairy forage system (corn-soybean-alfalfa)**
  - **Grazed pasture**
  - **Biofuel feedstock crops (switchgrass and reed canary grass)**

PRODUCTS

1. A national database of GHG flux and C storage.
2. Regional and national guidelines of management practices.
3. Development and evaluation of computer models.
4. Summary papers for use by action agencies and policy makers.

Sub-networks

- For internal and external collaborations.
- To provide cross-regional data.
- To address specific questions that may be posed to the GRACEnet project.

A national database of GHG flux and C storage.

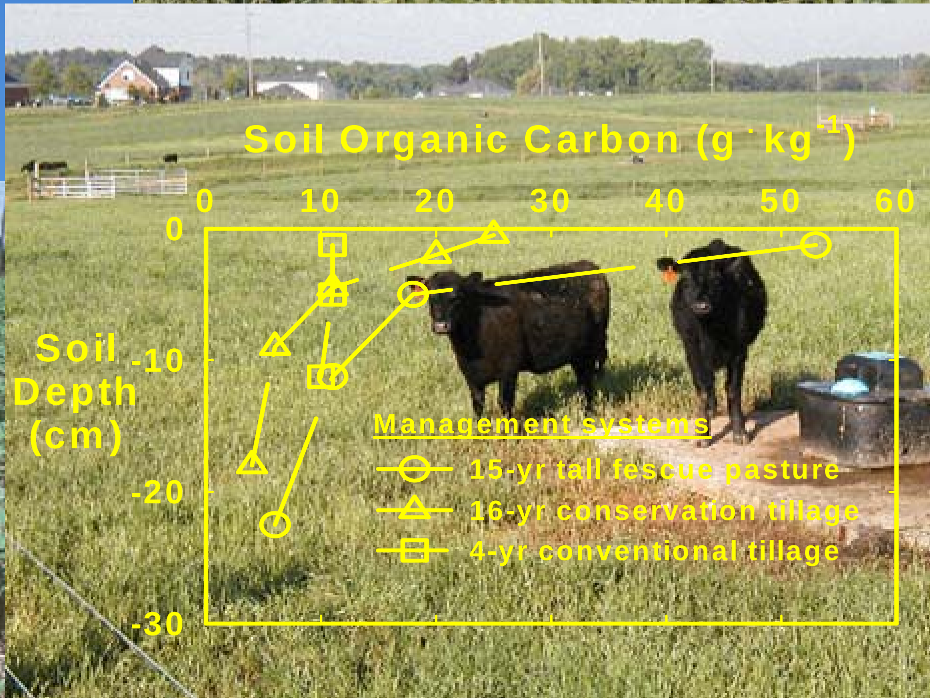
- The data base format has been designed and GRACEnet locations have agreed upon it.
- The data base is up on a server site
- Experimental data is being solicited from all GRACEnet locations for input into the database as it becomes available.

GRACEnet

Database of soil C and trace gas flux for crop, pasture and rangeland systems in the USA.

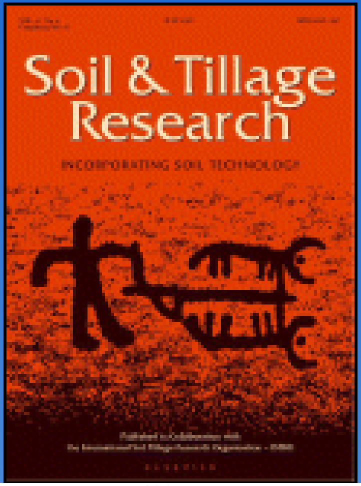
Long-term studies of:

- **Pasture (nutrient source x endophyte x grazing)**
- **Cropland (tillage x nutrient source; cover crop management)**
- **Integrated crop-livestock (tillage x N source x cover crop management)**



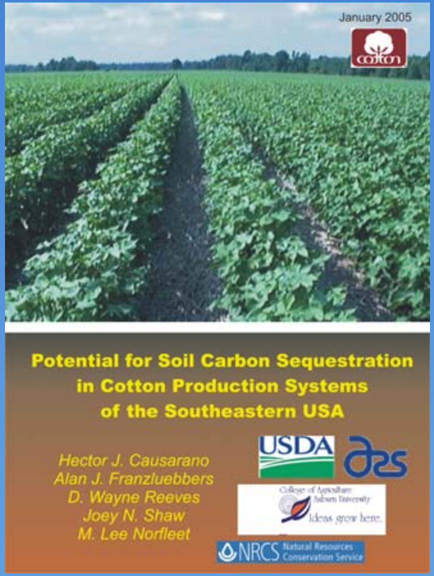
GRACEnet

Regional and national publications and guidelines of management that reduce GHG intensity, applicable for use by producers, federal and state agencies and C brokers.



Greenhouse Gas Contributions and Mitigation Potential in Agricultural Regions of North America

Special issue (Vol 83, August 2005)



Lab publication commissioned by Cotton Incorporated (January 2005)

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Environmental Pollution xx (2007) 1–18

ENVIRONMENTAL POLLUTION

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Review

Agricultural opportunities to mitigate greenhouse gas emissions☆,☆☆

Jane M.-F. Johnson [a,*], Alan J. Franzluebbers [b], Sharon Lachnicht Weyers [a], Donald C. Reicosky [a]

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Received 4 June 2007; accepted 10 June 2007

Management options can be used to reduce agriculture's environmental impacts.

GRACEnet

Summary paper for action agencies and policy makers based on the current state of knowledge

AGRICULTURAL EXHAUST: A REASON TO INVEST IN SOIL

Alan J. Franzluebbers, Ronald F. Follett, Jane M.F. Johnson, Mark A. Liebig, Edward G. Gregorich, Timothy B. Parkin, Jeffrey L. Smith, Stephen J. Del Grosso, Michael D. Jawson, Dean A. Martens

98A | JOURNAL OF SOIL AND WATER CONSERVATION M|J 2006

Reprinted from the *Journal of Soil and Water Conservation*
Volume 61, Number 3

GRACEnet

Evaluation and modification of computer models created to assess management effects on net GHG emission.

Effectiveness of the soil conditioning index as a carbon management tool in the southeastern USA based on comparison with EPIC

D.A. Abrahamson, M.L. Norfleet, H.J. Causarano, J.R. Williams, J.N. Shaw, and A.J. Franzluebbers

94 JOURNAL OF SOIL AND WATER CONSERVATION

Simulating Field-Scale Soil Organic Carbon Dynamics Using EPIC

Soil Sci. Soc. Am. J. 71:1174-1185
doi:10.2136/sssaj2006.0356

SSSAJ: Volume 71: Number 4 • July–August 2007

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CQESTR

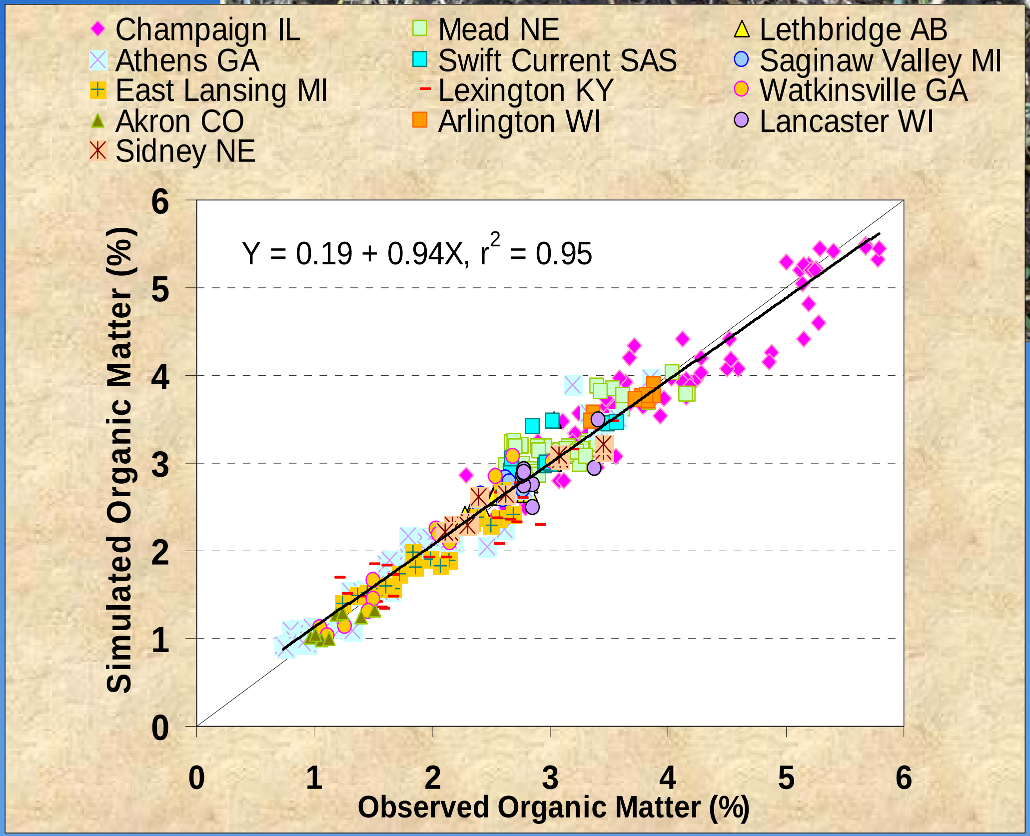
Evaluation and modification of computer models created to assess management effects on net greenhouse gas emissions.

CQESTR Development:
Decision support tool for managing soil carbon.

USDA-ARS-CPCRC
Pendleton, OR

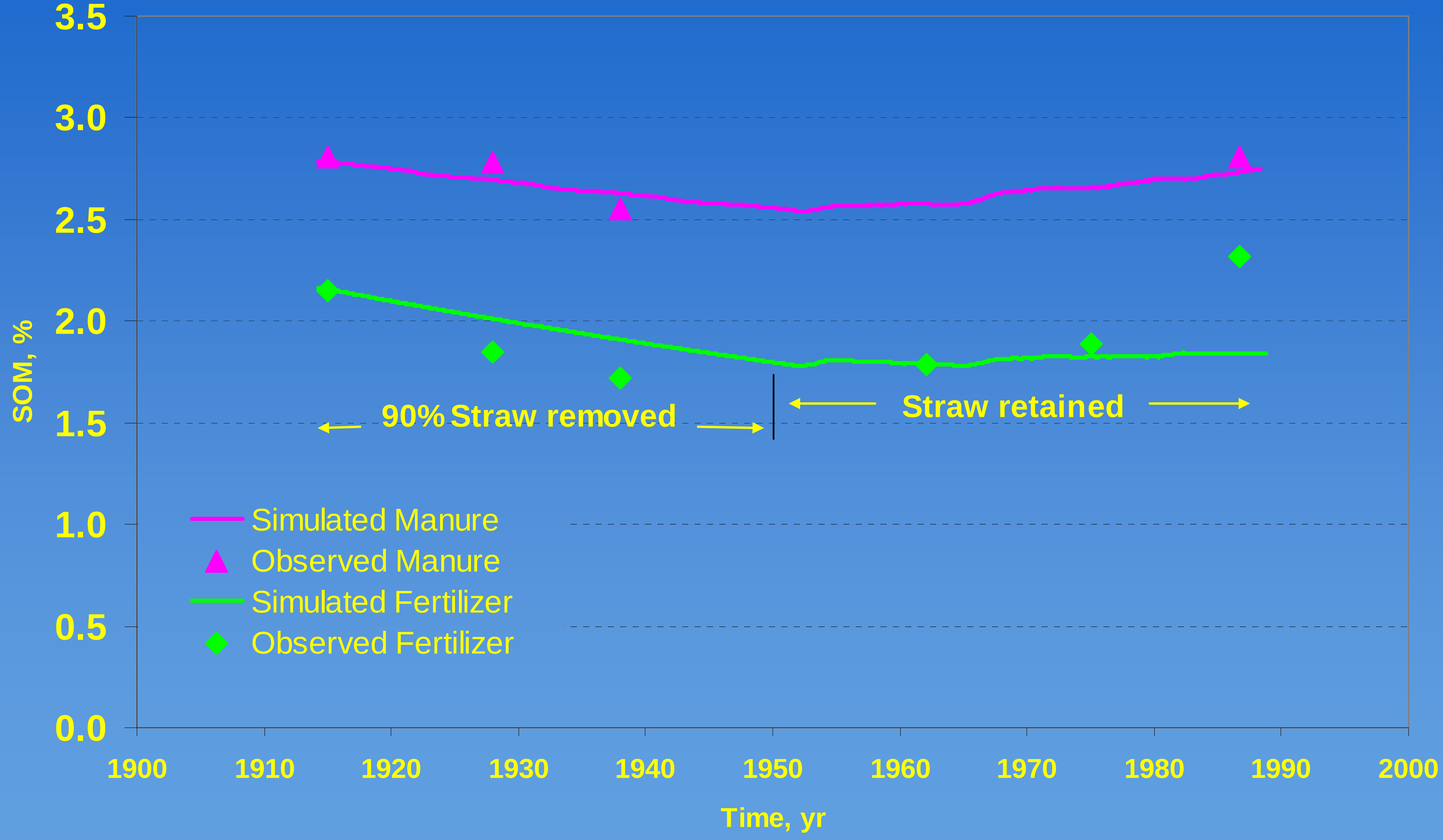
CQESTR Development:
Decision support tool for managing soil carbon

306 pairs of observed and simulated SOM values are well correlated (r^2 = 95%, P < 0.0001) with a 1:1 correspondence for the majority of values.



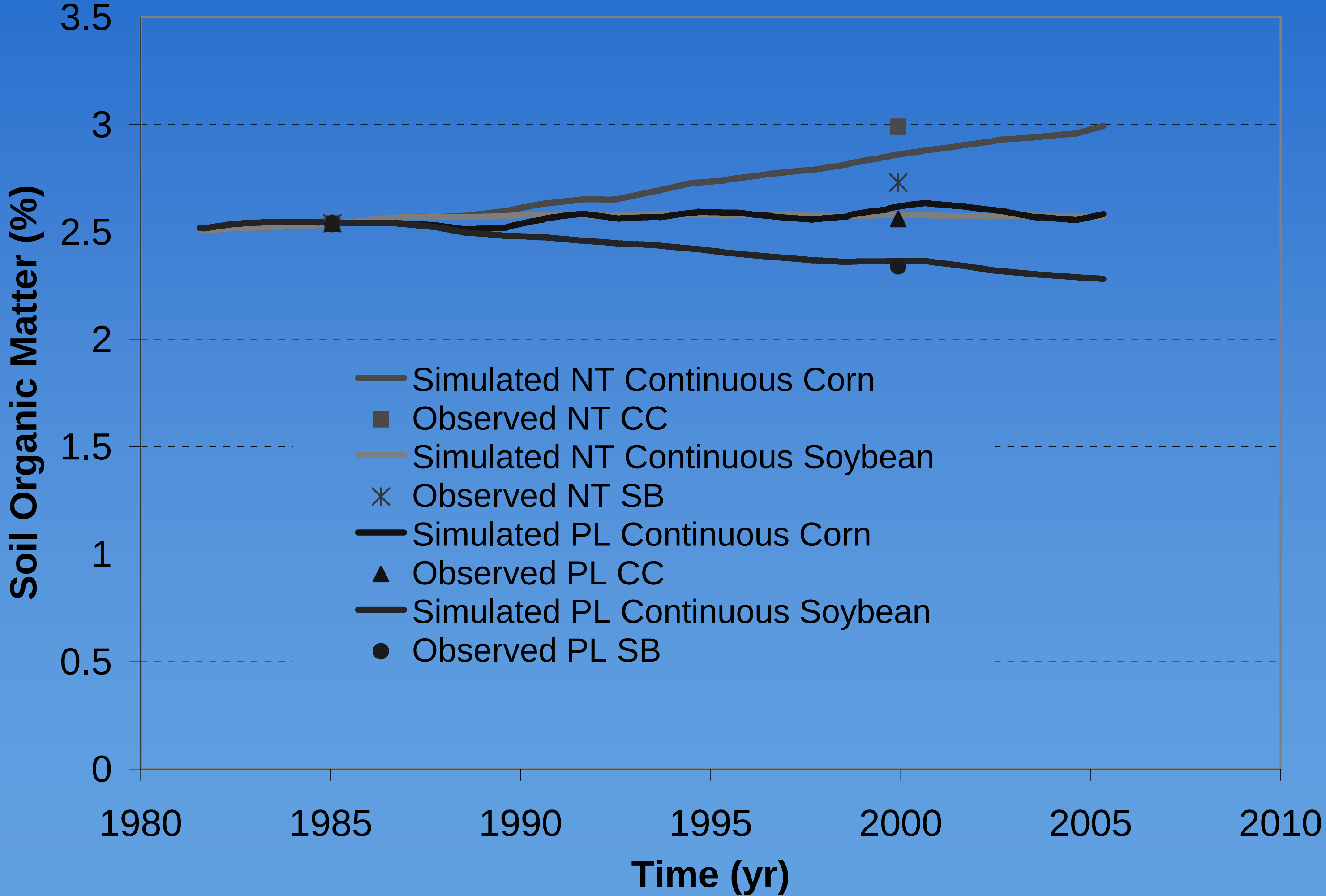
USDA-ARS-CPCRC
Pendleton, OR

Winter wheat, residue management change, ca 1950 moderately drained silt loam (Sanborn Field, Columbia, MO)



USDA-ARS-CPCRC
Pendleton, OR

CQESTR predictions for a moderately well drained silty clay loam soil (0-24") at Lincoln, NE

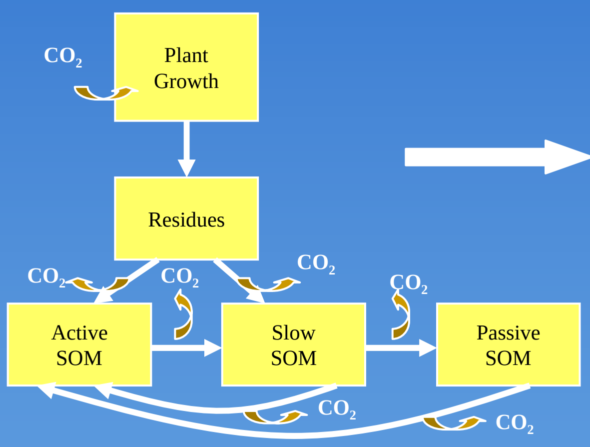


GRACEnet Provides Data to Develop, Run, and Test Models

DAYCENT Model

GRACEnet
Model Input Data

- Land Management
- Soil properties
- Weather
- Etc.

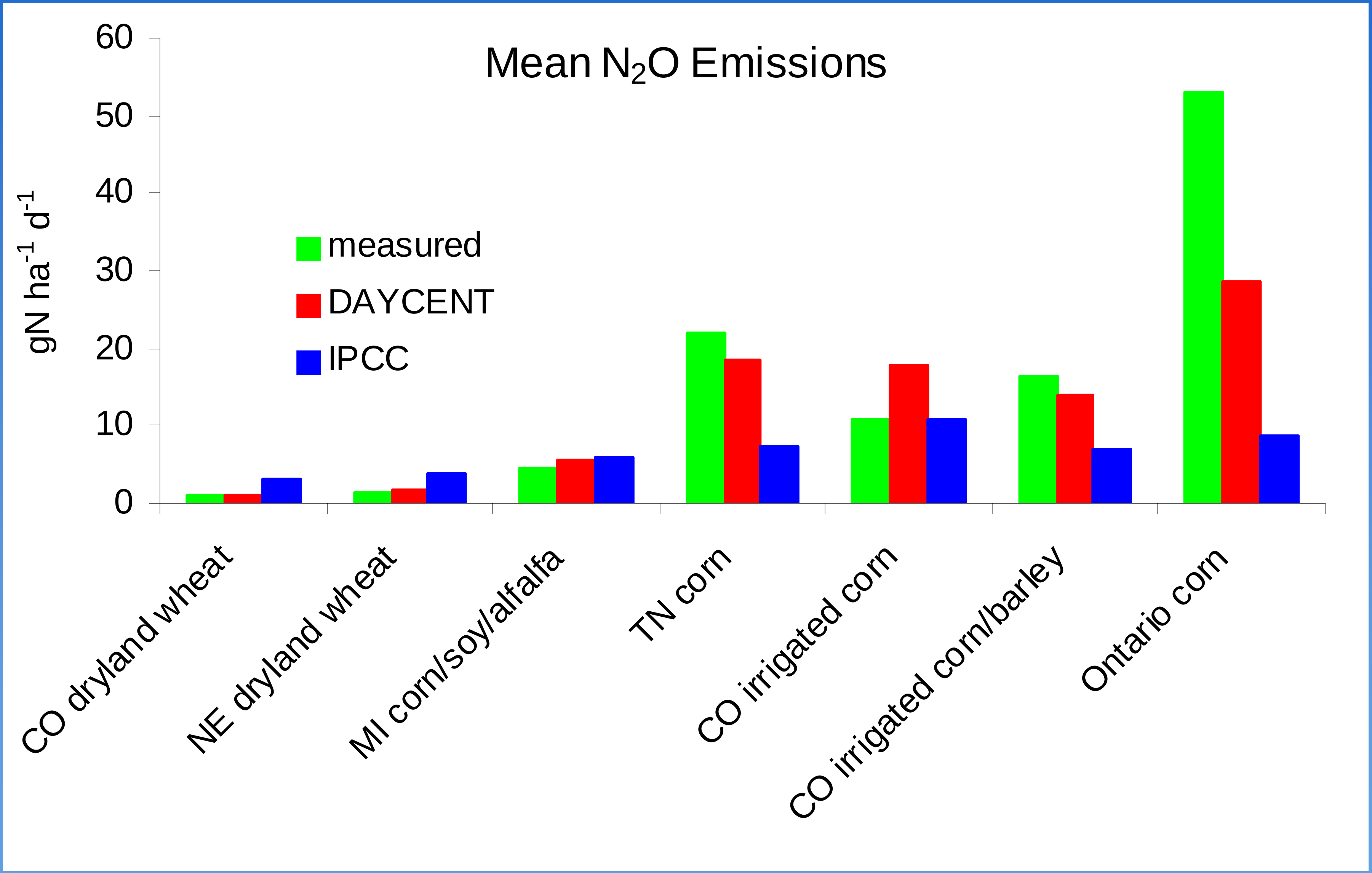


Multi-Scale GHG Flux Estimates
(Site, Regional and National Scales)

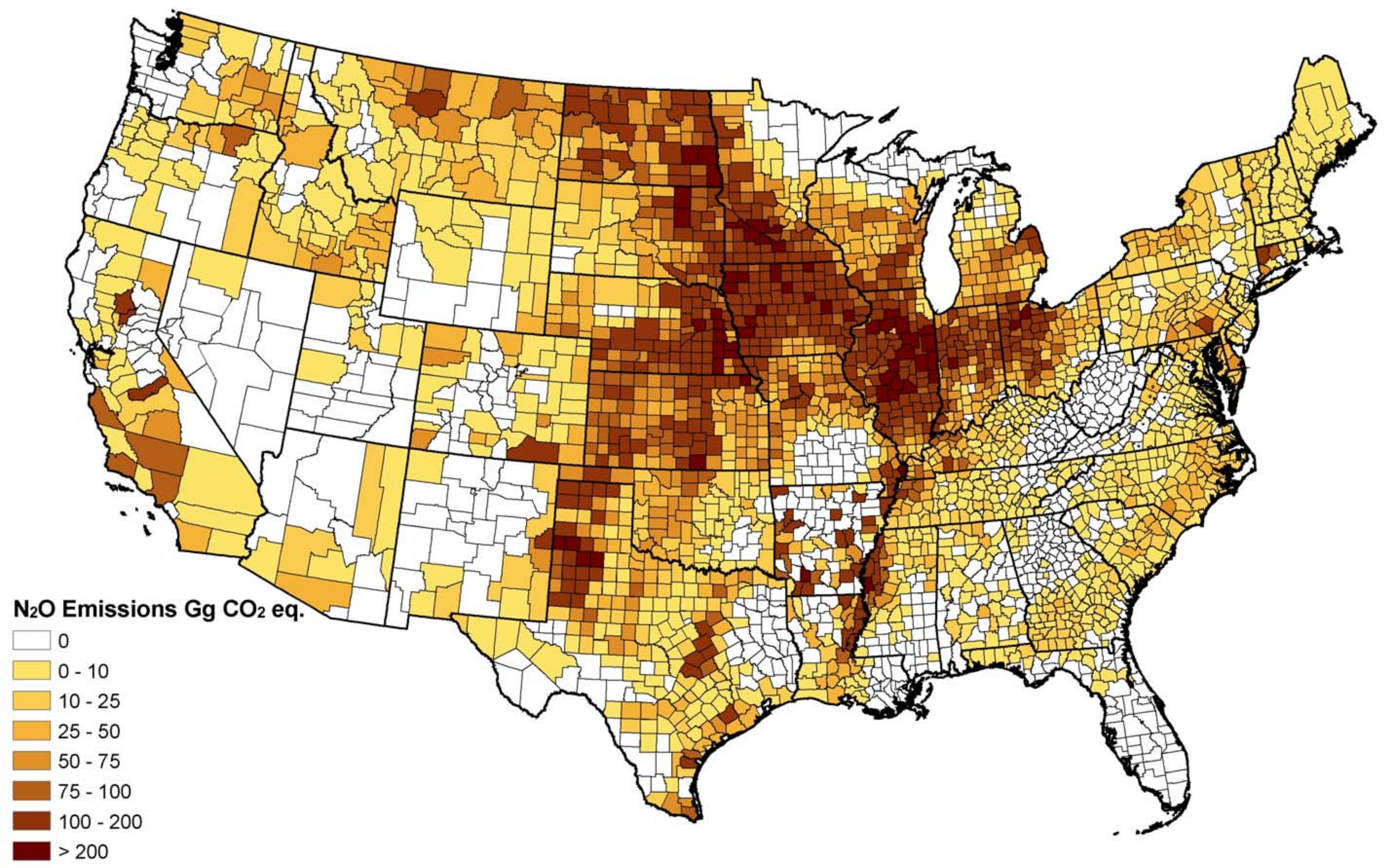
GRACEnet
Model Testing Data

- Gas flux
- Soil C, N
- Crop yields
- Etc.

DAYCENT and IPCC Emissions vs. Measurements



DAYCENT N_2O Emissions from Major Crops for USDA GHG Inventory



Expert input for National or Regional needs:

- **Global Change Climate Office of USDA**
- **Other Government Agencies (EPA, etc.)**
- **The Chicago Carbon Exchange**
- **The North Dakota Farmers Union**
- **Northwest Direct Seed Association**
- **Industry**
- **Others**

USDA

United States
Department of
Agriculture

Office of the
Chief Economist

Global Change
Program Office

Technical Bulletin XXXX

U.S. AGRICULTURE AND FORESTRY GREENHOUSE GAS INVENTORY: 1990-2005


The End
Thank you
USDA-Agricultural Research Service;
Fort Collins, CO; USA