# Impacts of Land Conversion for Biofuel Cropping on Soil Organic Matter and Greenhouse Gas Emissions

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# Questions Addressed

- How do current and previous land use interact to control soil properties and emissions?
- How can soil quality be maintained/enhanced?
- Life Cycle Analysis?

# Biofuel Cropping Systems

## GHG Sources:

- $N_2O$ (direct and indirect)
- Chemical Inputs
- Farm Machinery
- Soil C
- Feedstock Conversion

## GHG Sinks:

- Displaced Fossil Fuel
- Soil C
- $CH_4$ Oxidation

# The Energy Independence and Security Act of 2007

- 7 billion gallons ethanol out of in 180 billions consumed in 2007
- 36 billion gallons of biofuel by 2022
- Ethanol - 20% reduction in GHG compared to gasoline
- Biodiesel - 50% reduction
- Cellulosic - 60% reduction

# Global Warming Potential

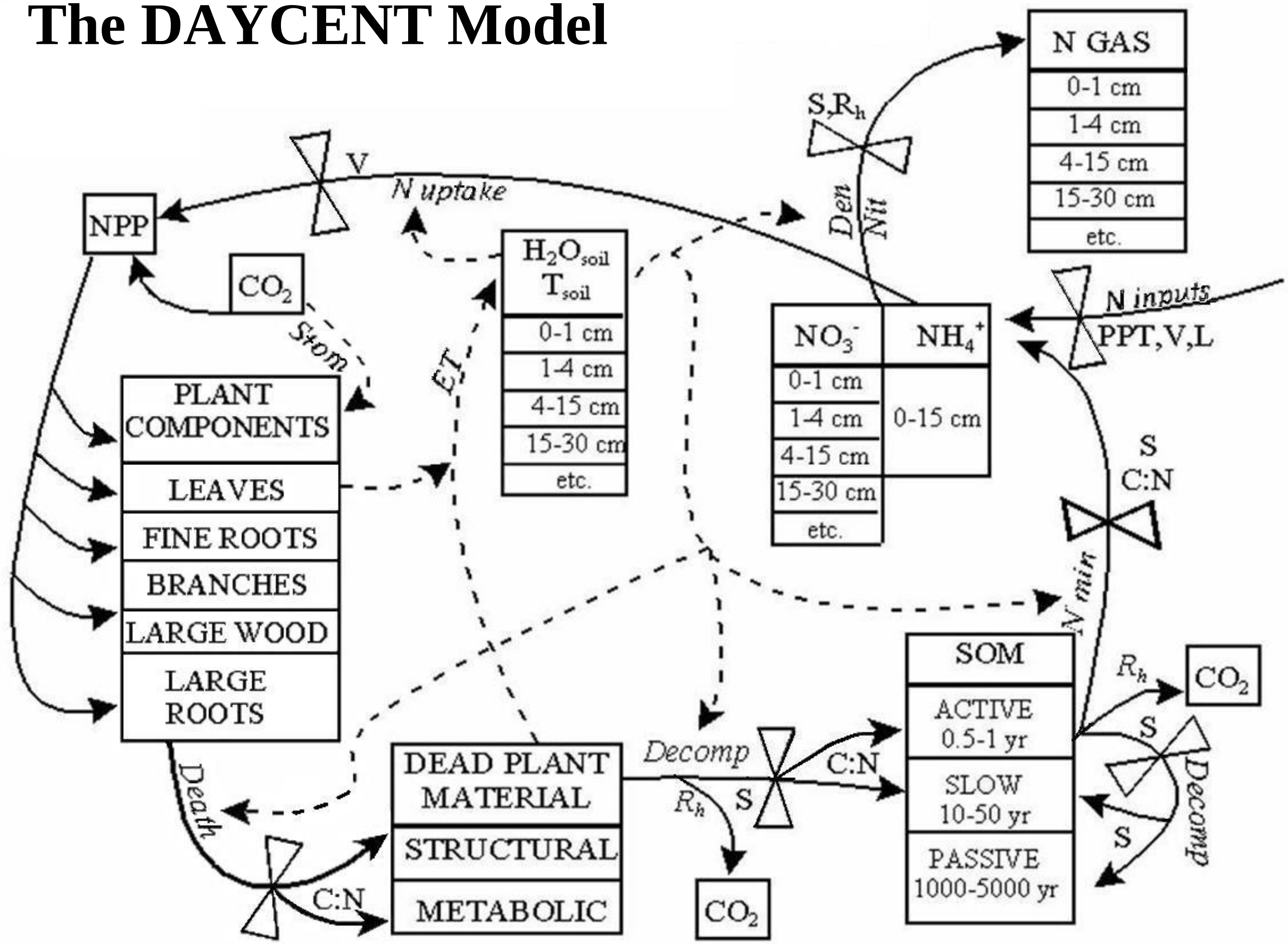
| Gas | Atmospheric lifetime (yrs) | GWP |
|---|---|---|
| $CO_2$ | 50-200 | 1 |
| $CH_4$ | 12 | 21 |
| $N_2O$ | 120 | 300 |

# DAYCENT Ecosystem model

Primary tool for:

- Soil GHG emissions
- $NO_3$ leaching
- Crop yields

# The DAYCENT Model



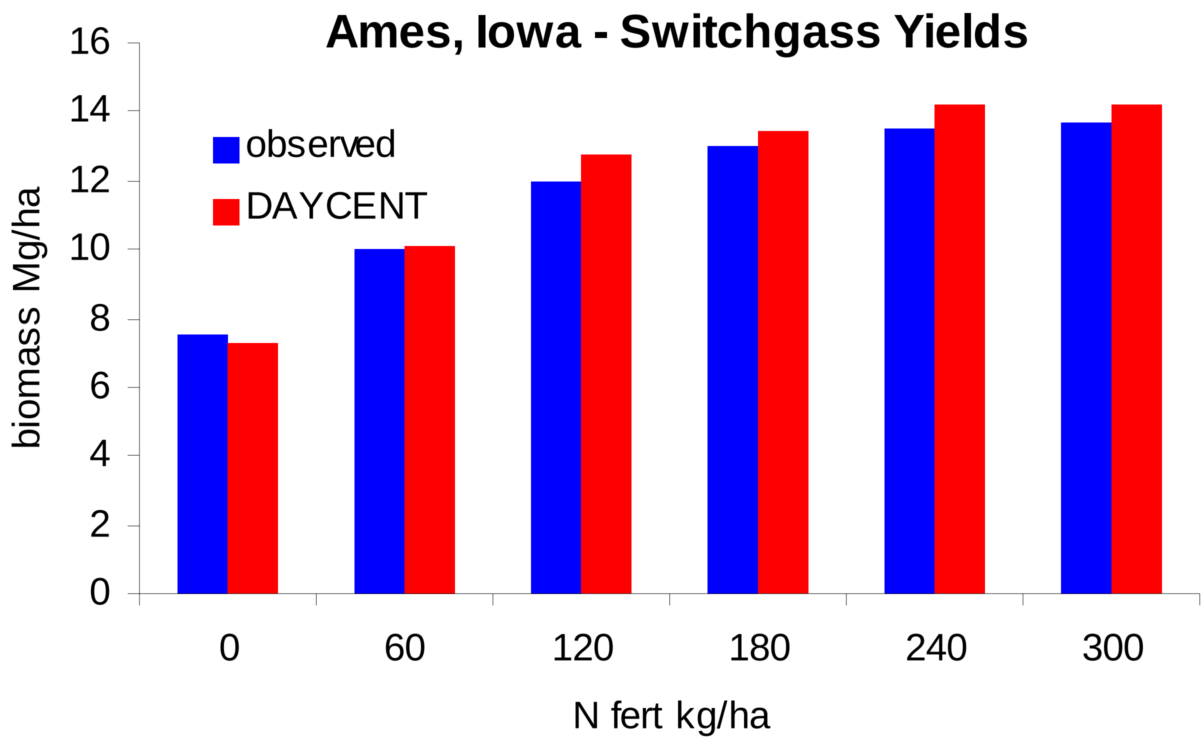

= C, N flows
= Feedbacks, information flow
= Control on process
$H_2O_{soil}$ = Soil water content
$T_{soil}$ = Soil temperature
S = Soil texture

C:N = Carbon:Nitrogen ratio of material
V = Vegetation type
SOM = Soil Organic Matter
L = Land use
$R_h$ = Heterotrophic respiration

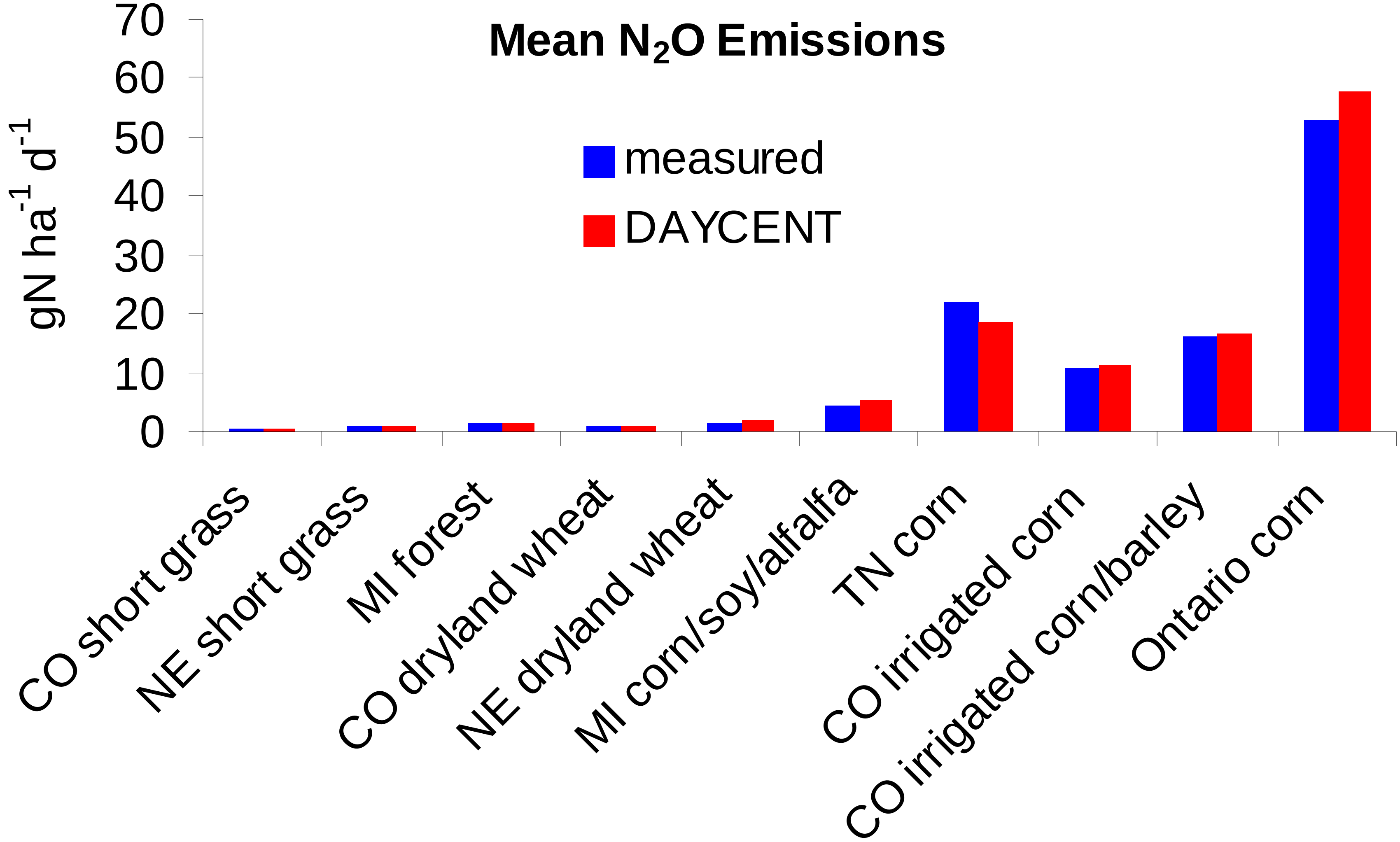
N GAS = $N_2O$, $NO_x$, $N_2$
Processes designated by *italics*
*Stom* = Stomatal conductance
*Death* = Plant component death
*Decomp* = Decomposition
*N inputs* = N Fixation, N deposition, N fertilization

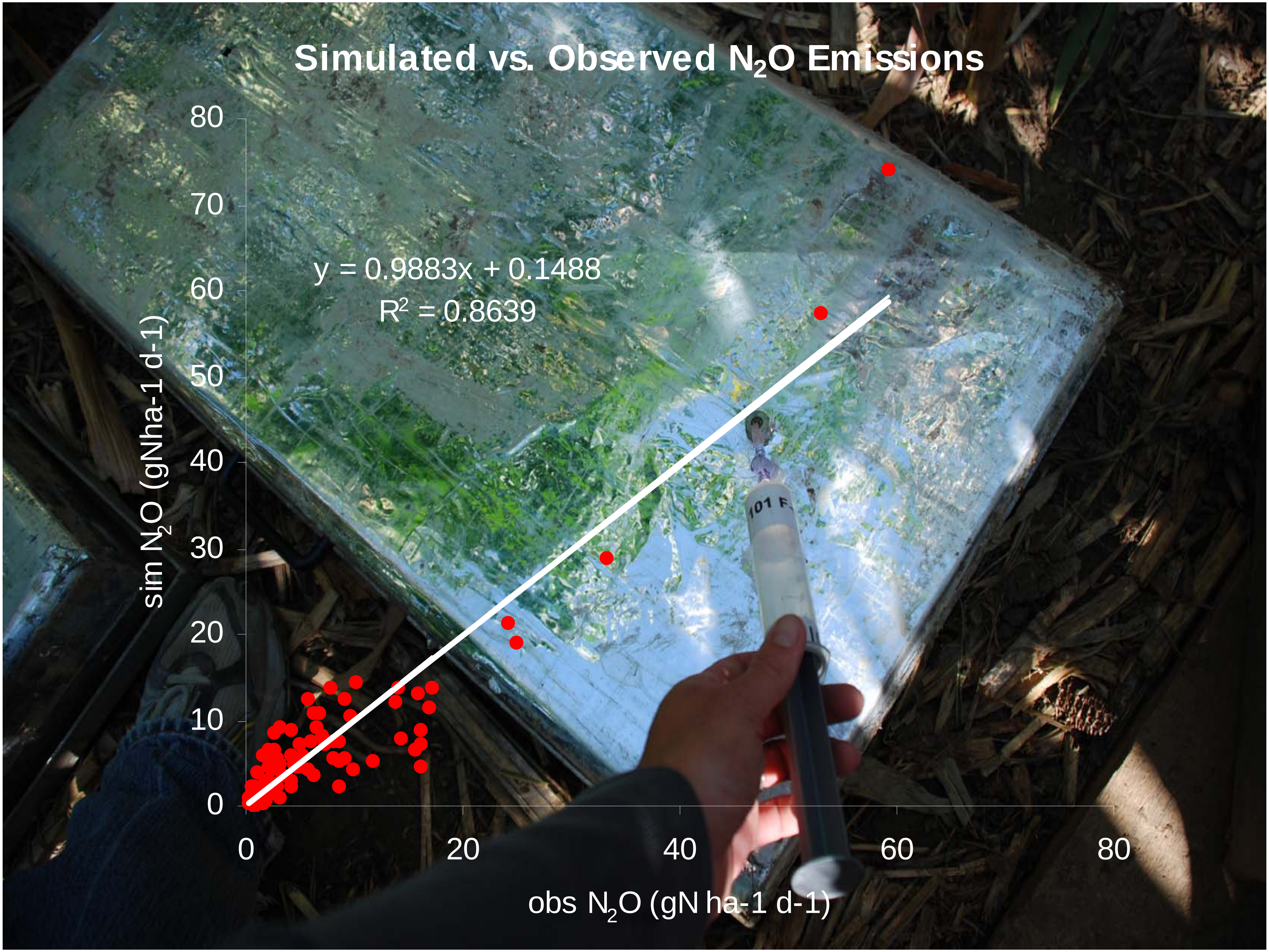
*Nit* = Nitrification
*Den* = Denitrification
*N min* = N mineralization
*ET* = Evapotranspiration

# Model Testing



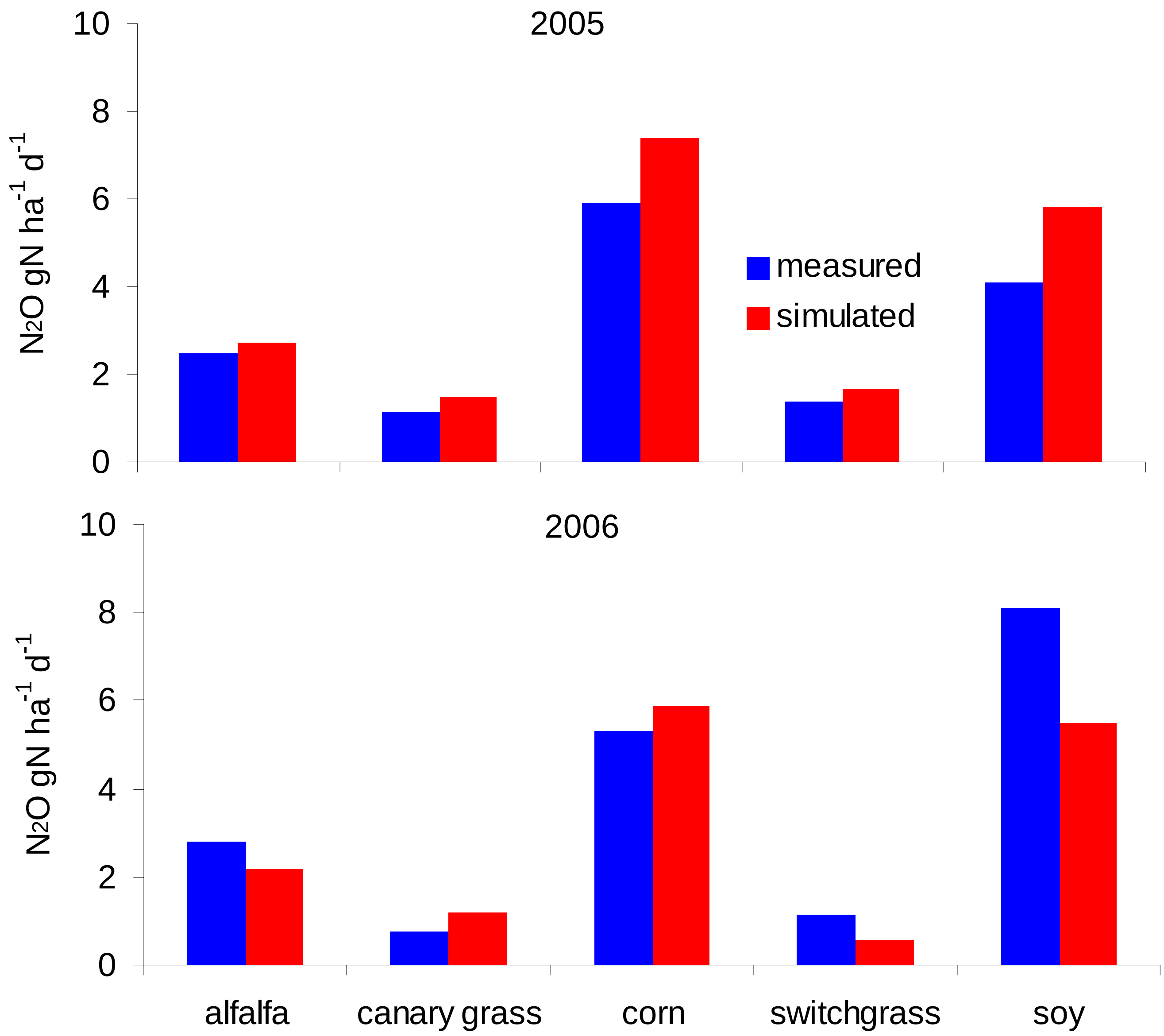
# Model Testing





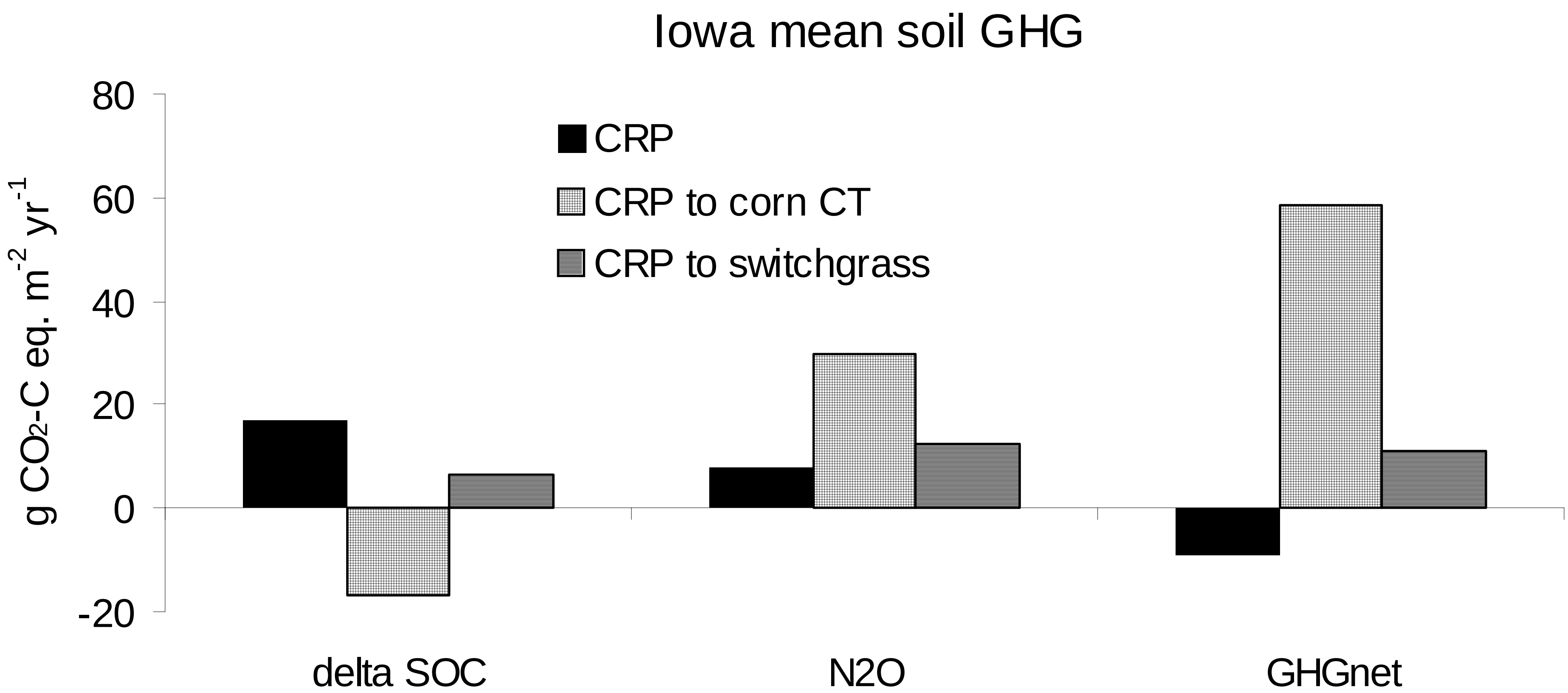
Simulated vs. Observed $N_2O$ Emissions
y = 0.9883x + 0.1488
$R^2$ = 0.8639
sim $N_2O$ (gNha-1 d-1)
obs $N_2O$ (gN ha-1 d-1)
0
10
20
30
40
50
60
70
80
0
20
40
60
80
101 F

# Observed and DAYCENT $N_2O$ for Biofuel Cropping Systems in Pennsylvania

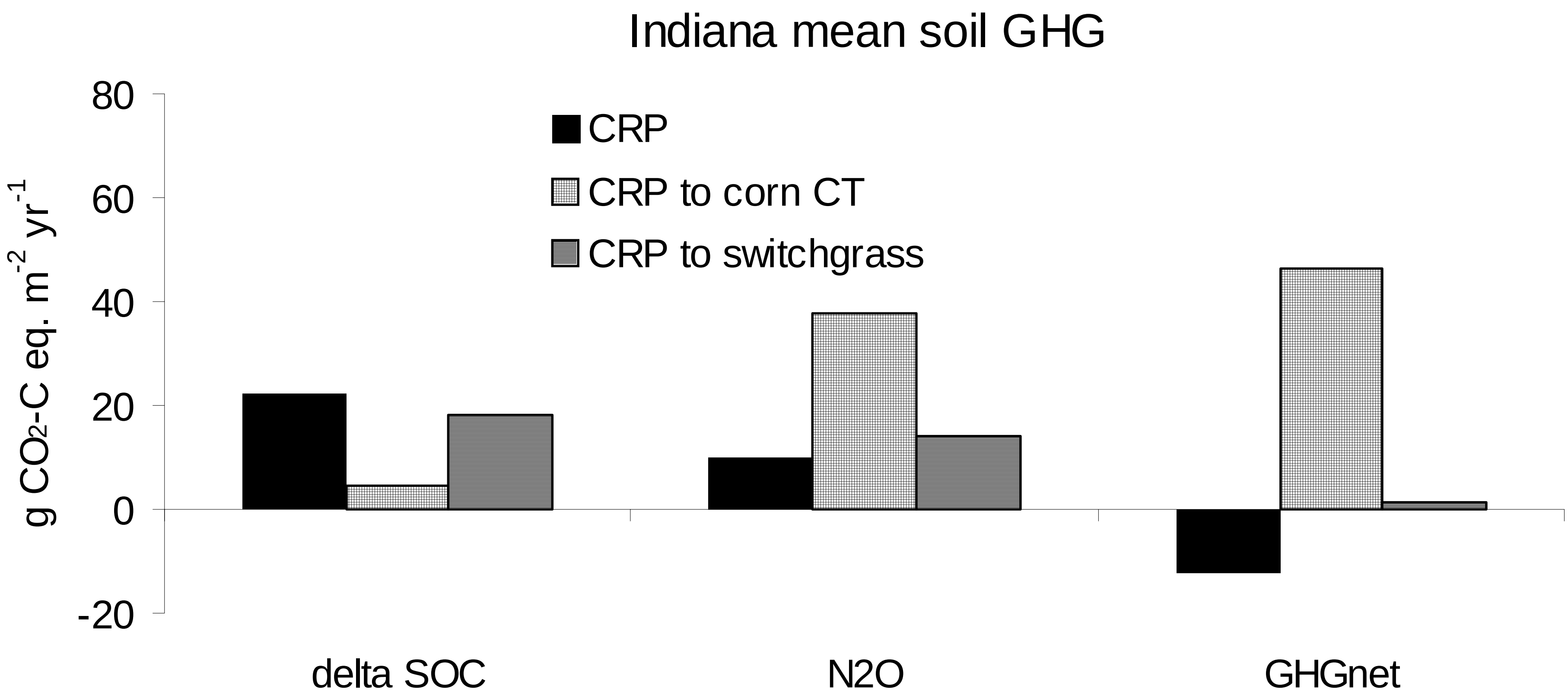


# CRP Conversion

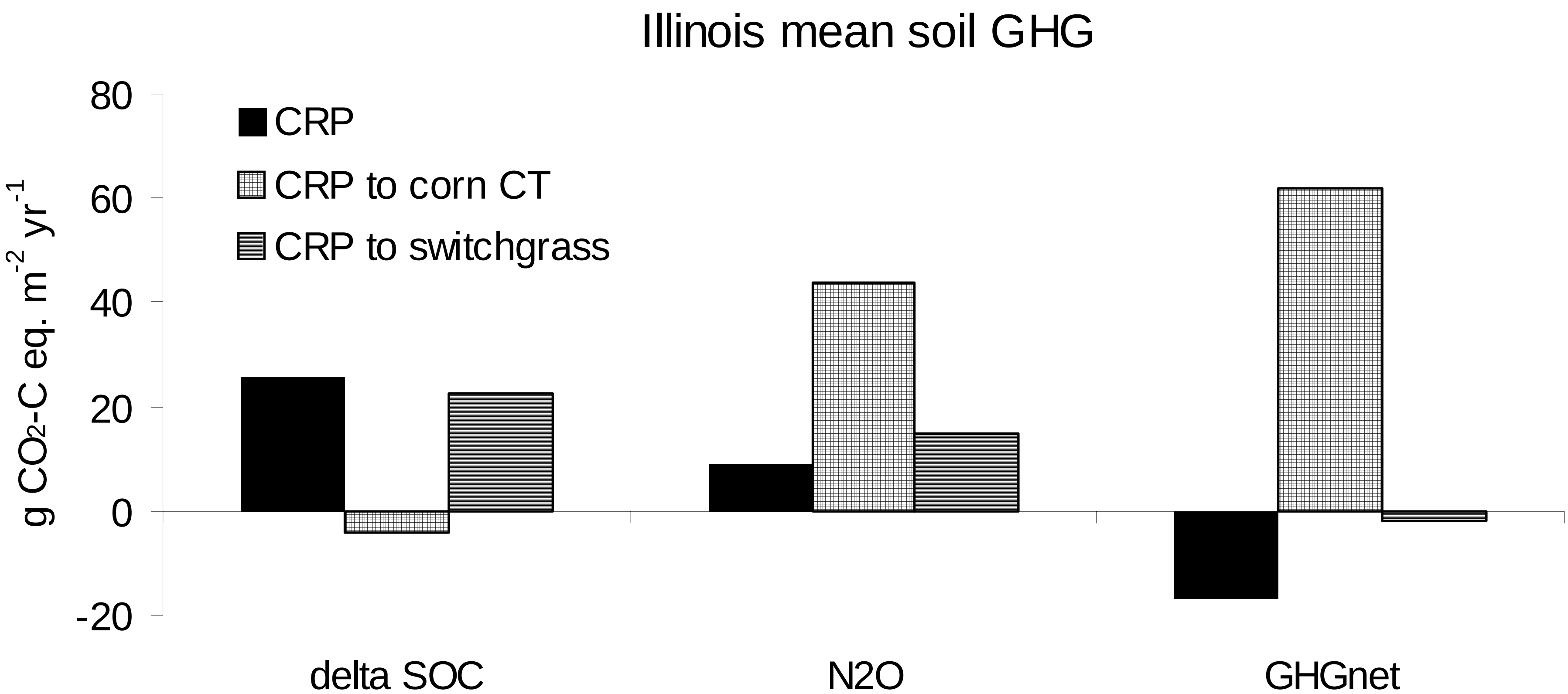
- CRP soils in US currently ~ 22 Tg $CO_2$ eq. sink
- What are the impacts of converting CRP land to biofuel production?
- Selected states where most of corn for ethanol is grown in USA: Illinois, Iowa, Indiana
- Results for 10 year annual means after conversion

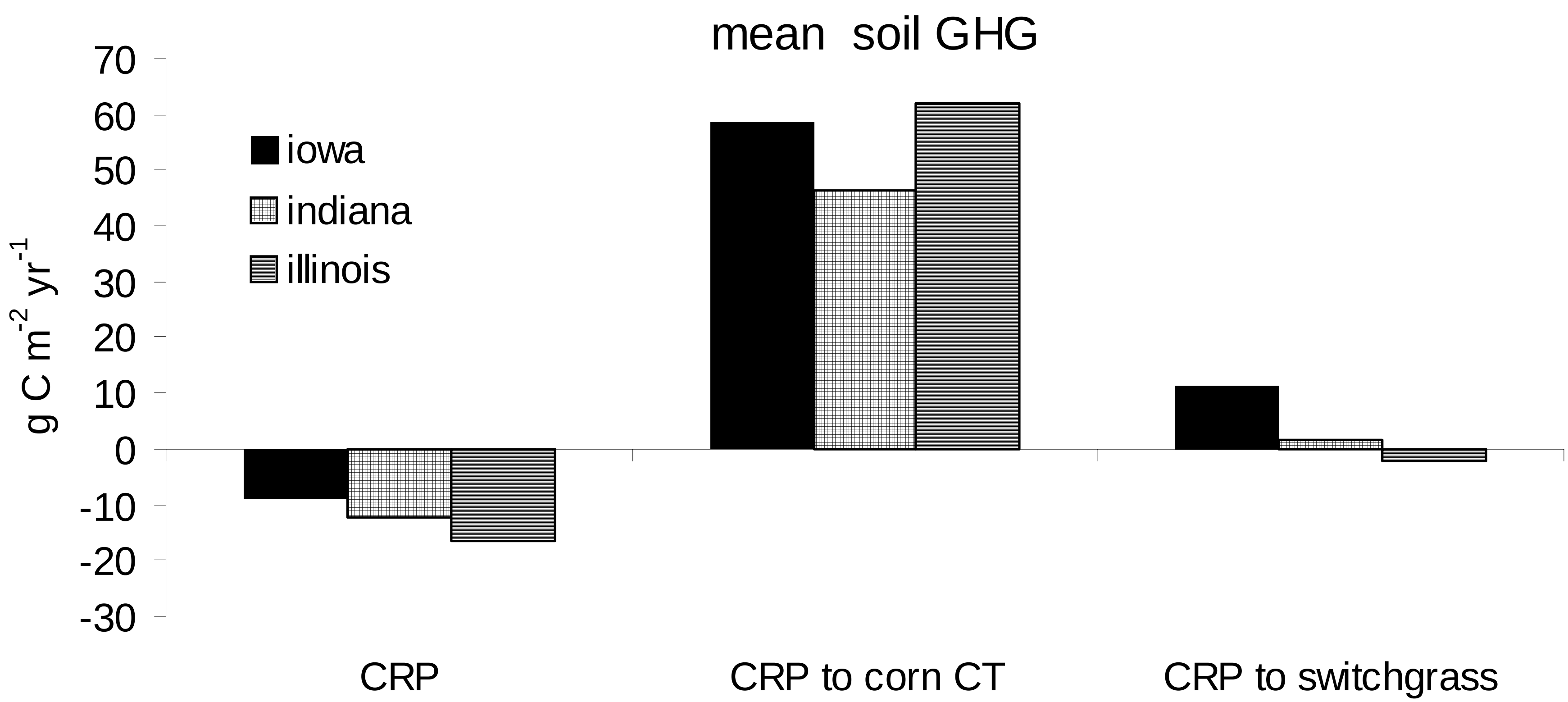


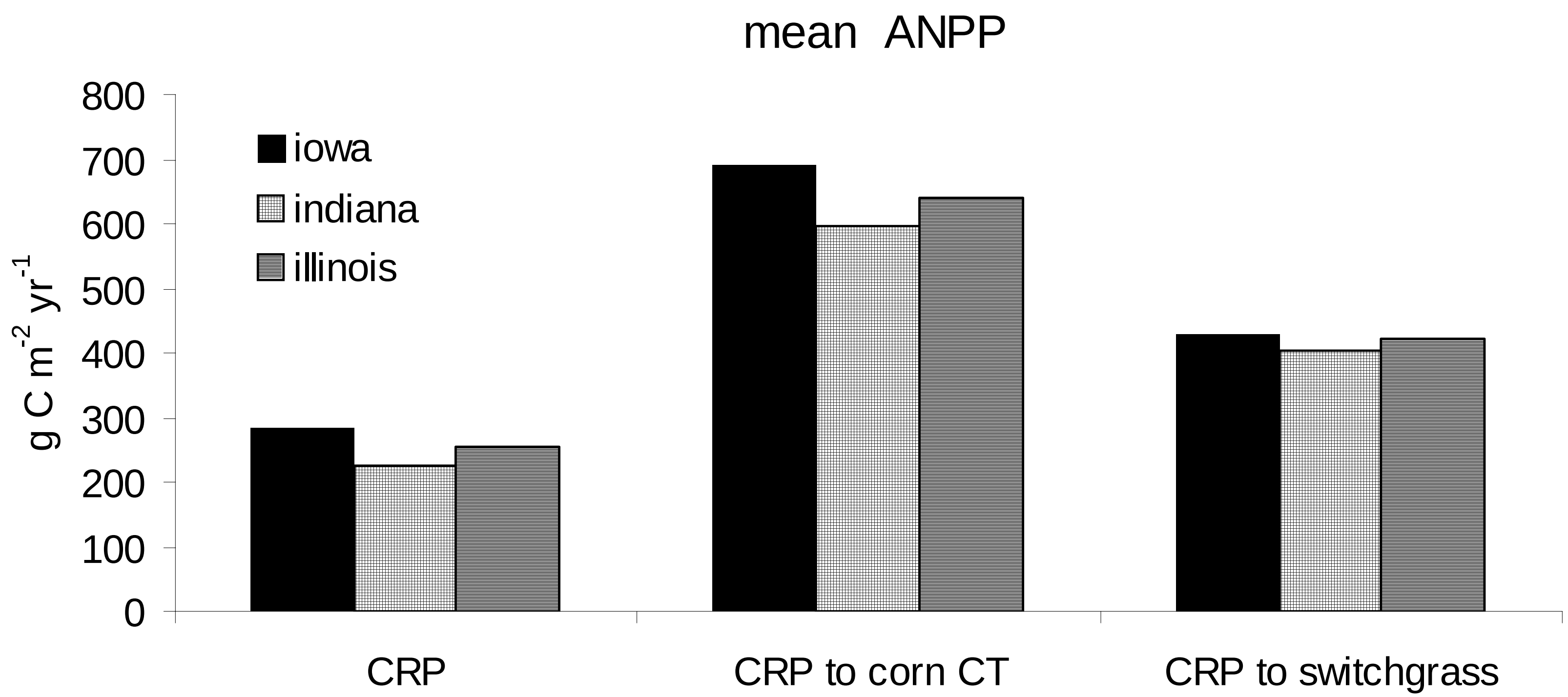
Iowa mean soil GHG
g CO2-C eq. m-2 yr-1
80
60
40
20
0
-20
CRP
CRP to corn CT
CRP to switchgrass
delta SOC
N2O
GHGnet



Indiana mean soil GHG
CRP
CRP to corn CT
CRP to switchgrass
g CO2-C eq. m-2 yr-1
80
60
40
20
0
-20
delta SOC
N2O
GHGnet


Illinois mean soil GHG
80
60
40
20
0
-20
g CO2-C eq. m-2 yr-1
CRP
CRP to corn CT
CRP to switchgrass
delta SOC
N2O
GHGnet


mean soil GHG
70
60
50
40
30
20
10
0
-10
-20
-30
g C m-2 yr-1
iowa
indiana
illinois
CRP
CRP to corn CT
CRP to switchgrass


mean ANPP
800
700
600
500
400
300
200
100
0
g C m-2 yr-1
iowa
indiana
illinois
CRP
CRP to corn CT
CRP to switchgrass

# Broaden Scope: Life Cycle Analysis

## Land Use Changes:

- Existing cropland converted to ethanol
- CRP converted to ethanol
- Pasture converted to ethanol

## Land Management Scenarios:

- Conventional till vs. no till
- Conventional vs. improved nitrogen fertilizers

## LCA:

- Soil GHG fluxes
    - Feedstock conversion
    - Other GHG sinks/sources

# Tools and Data Sources for GHG Life Cycle Analysis

- Soil GHG fluxes and crop yields -DAYCENT biogeochemical model

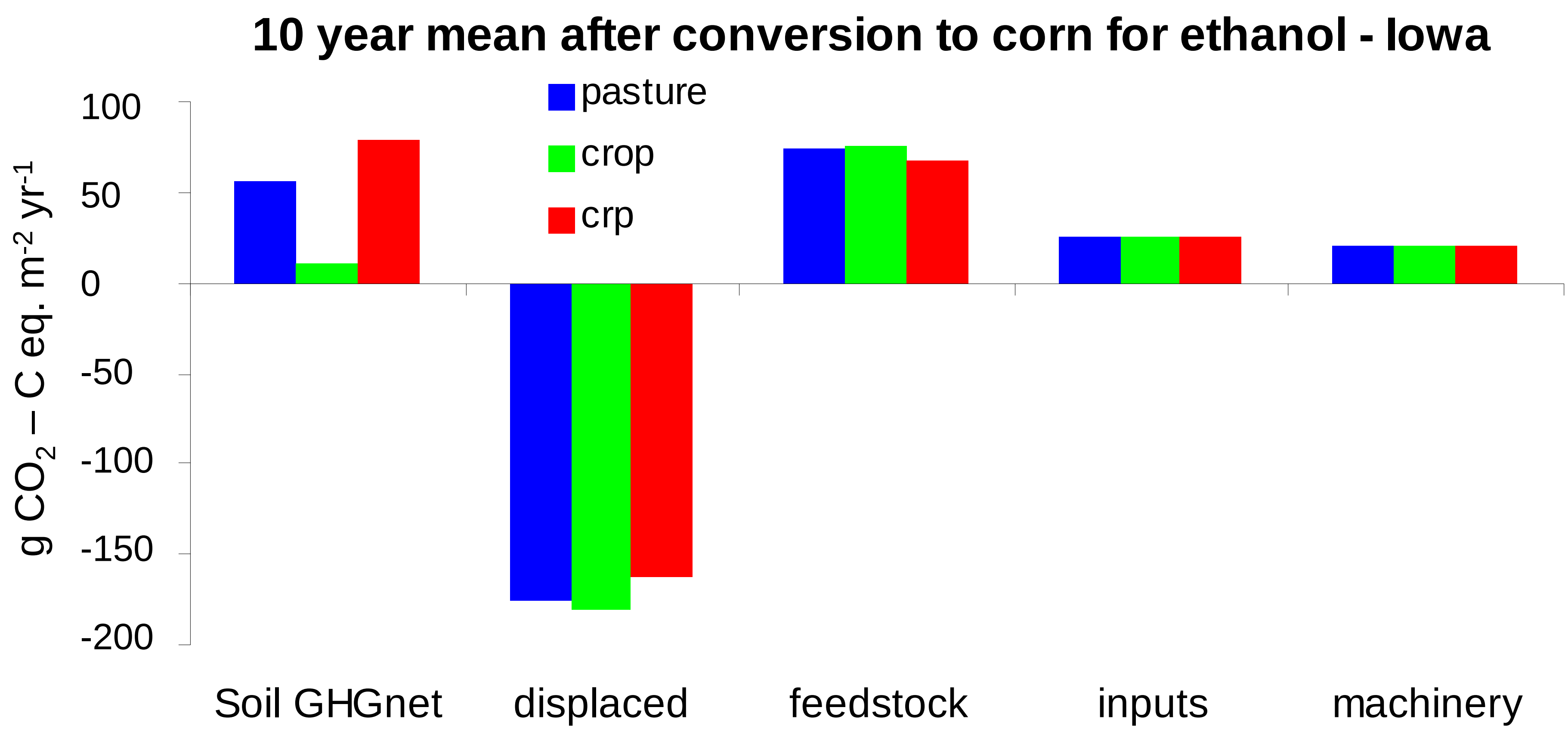
- GHG from farm machinery operation – IFSM

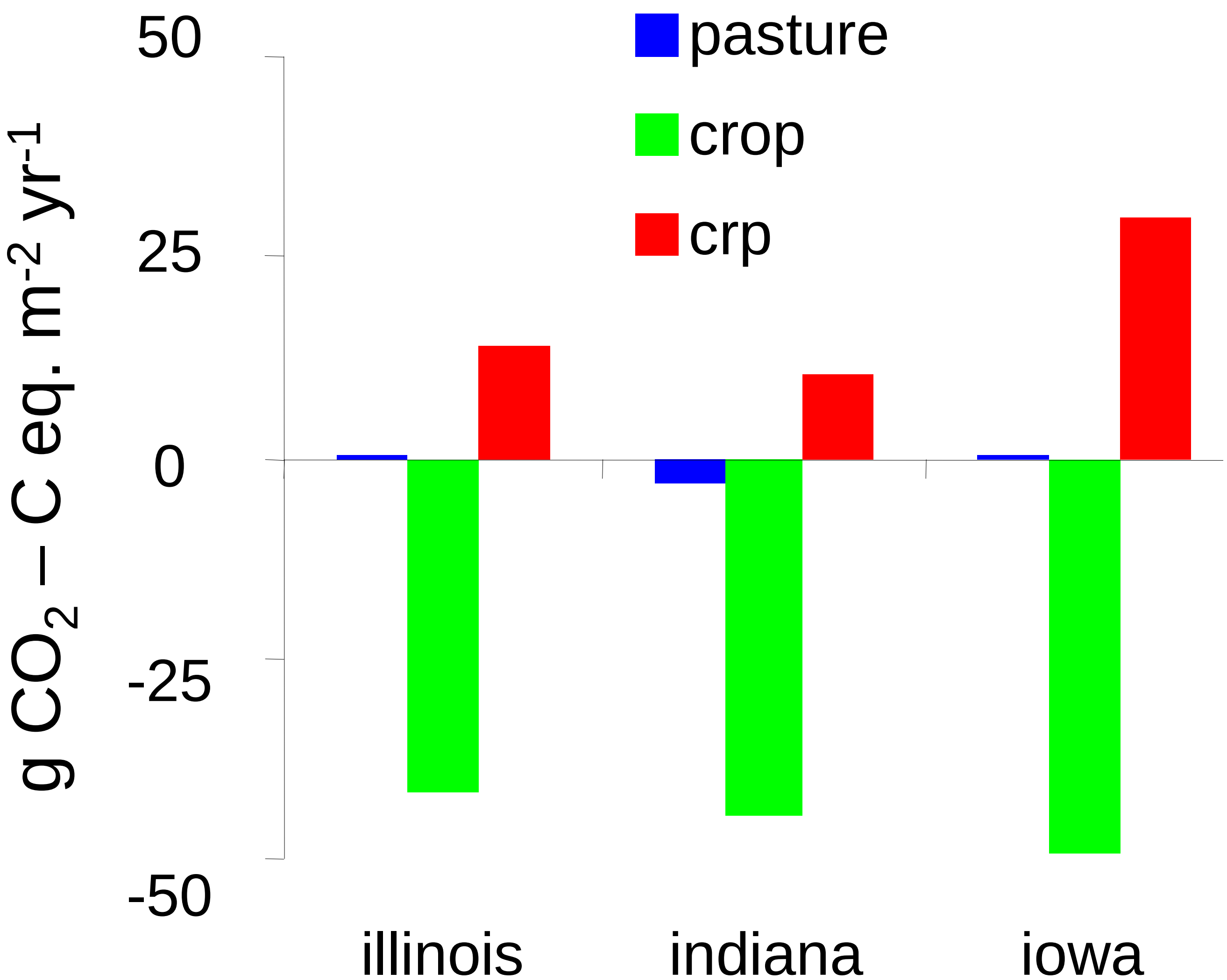
- Feedstock conversion into ethanol - West and Marland 2002

- Displaced fossil fuel - Sheehan et al. 1998, 2004.

- Energy savings for co-products - Farrell et al. 2006

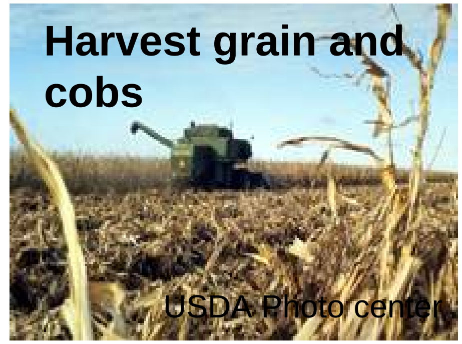
# Components of LCA GHGnet



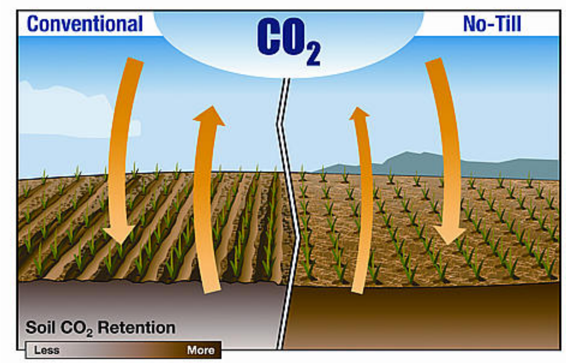

50
25
0
-25
-50
g $CO_2$ – C eq. $m^{-2}$ $yr^{-1}$
pasture
crop
crp
illinois
indiana
iowa

# How can we improve?

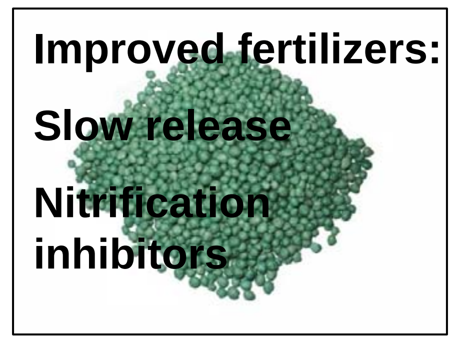






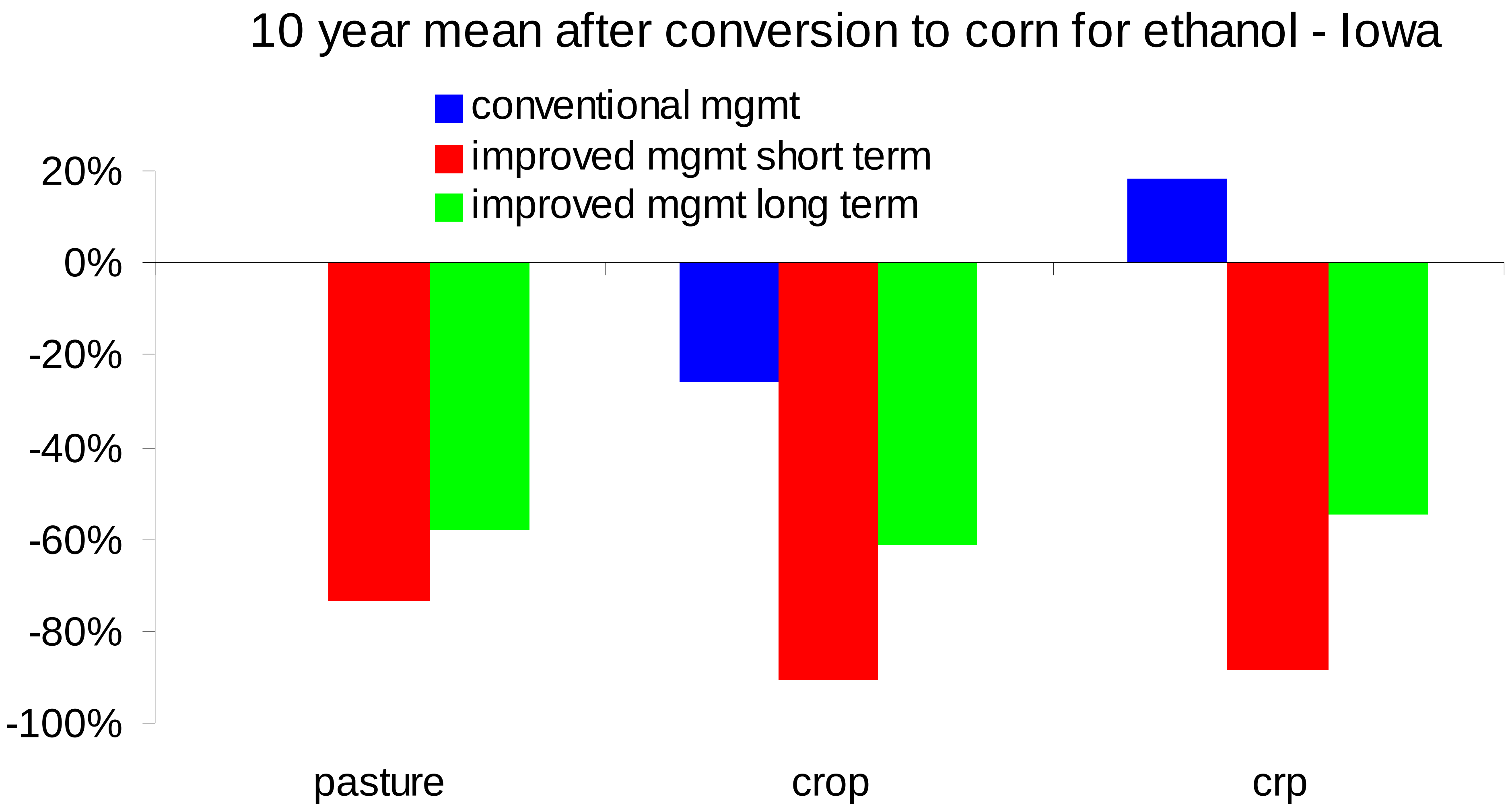








# Reduction in GHGnet compared to fossil fuel GHG



# Conclusions

•CRP land converted to corn ethanol is a GHG source under conventional management

•CRP land converted to switchgrass is a small soil GHG source

•Improved management can reduce $N_2O$ emissions and maintain soil C

•Need to consider full LCA, not just impacts on soil

•Gasified corn cobs can be used to power the conversion of grain to ethanol

•Also need to account for leakage, as well as impacts on habitat, etc.