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Climate, Water, and Ecosystems: A Future of Surprises

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Climate, Water, and Ecosystems: A Future of Surprises

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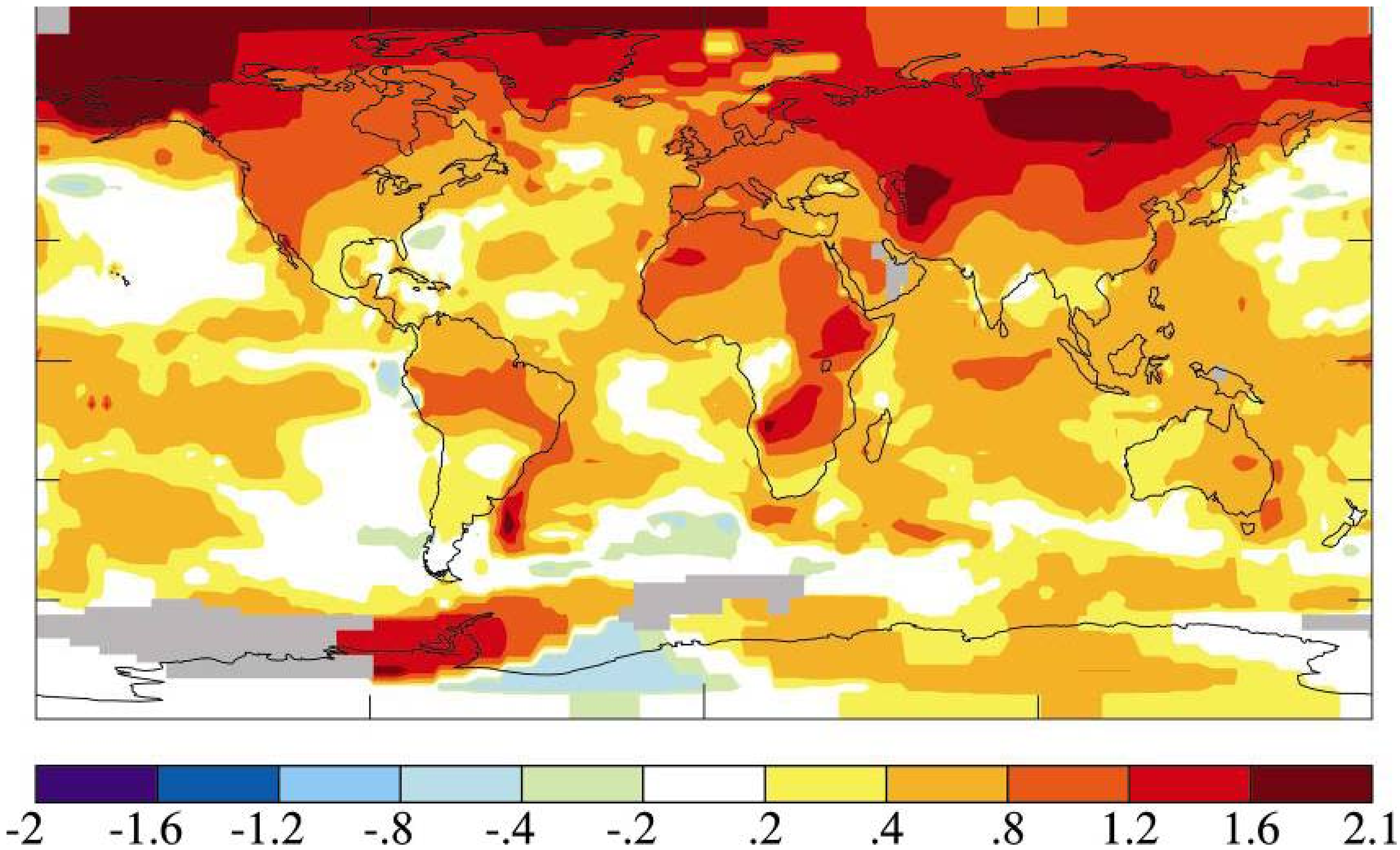
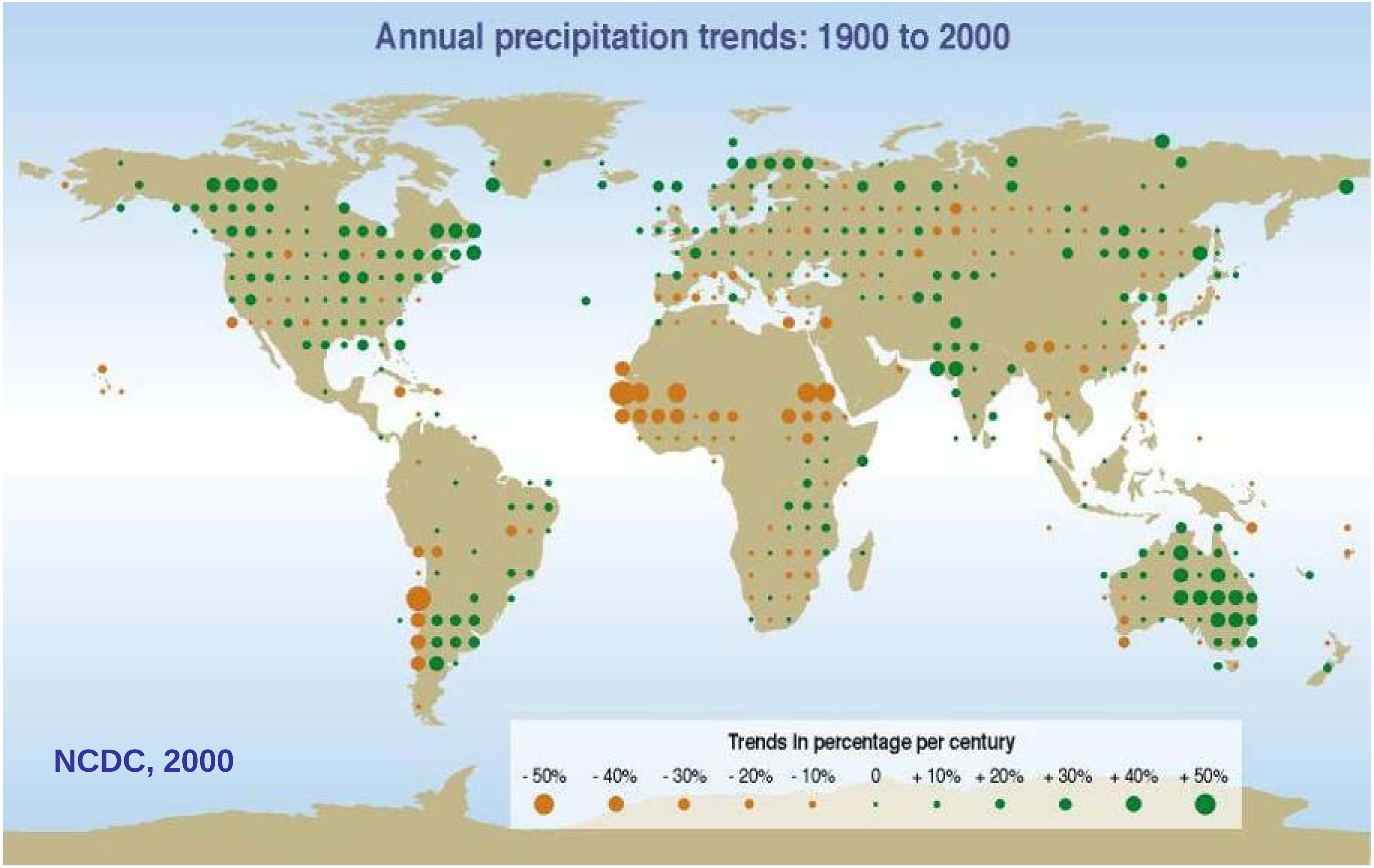
Climate change is not uniform geographically

Average T for 2001-2005 compared to 1951-80, degrees C



J. Hansen et al., *PNAS 103*: 14288-293 (2006)

And T is not the only factor that's changing

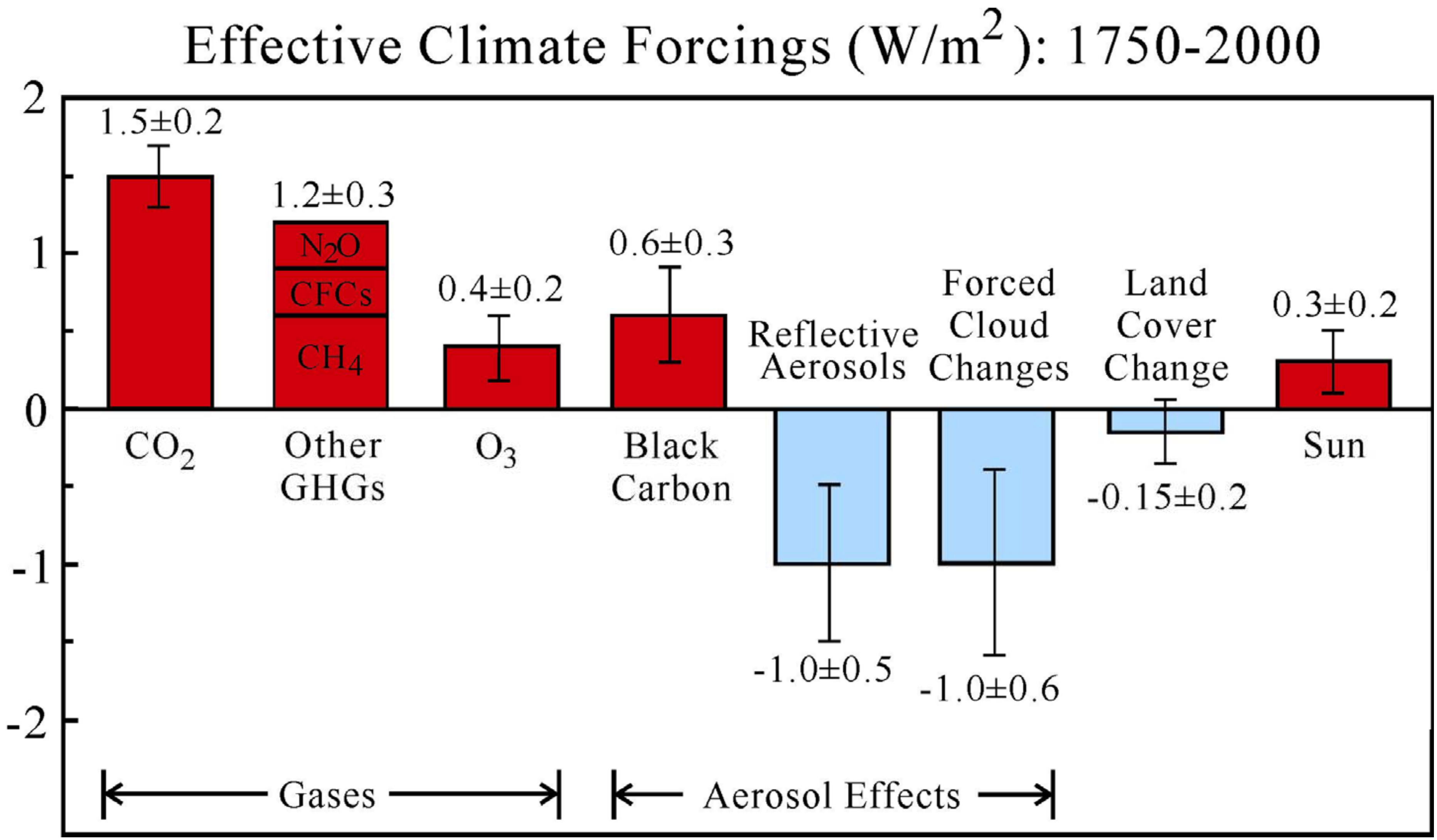


Effect is not uniform; most places getting wetter, some getting drier.

Mitigation and Adaptation to Climate Change By Design

- Carbon dioxide is primary greenhouse gas, but methane, nitrous oxide, CFC’s, ozone, and black soot also contribute to climate change.

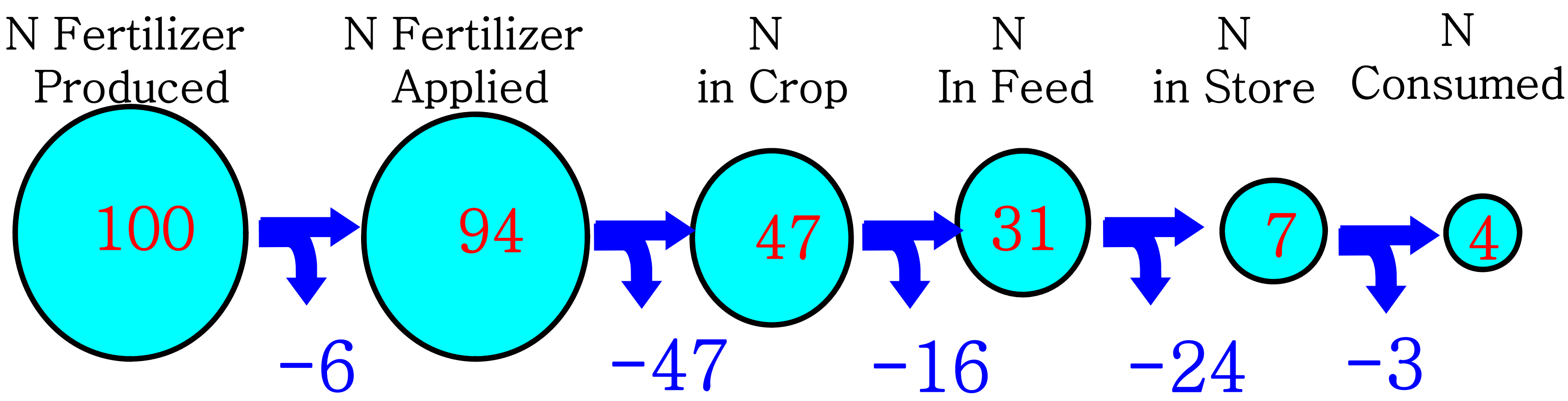
- Significant climate change mitigation benefits can be derived by reducing nitrous oxide and methane emissions from agriculture.



Climate forcing agents in the industrial era. “Effective” forcing accounts for “efficacy” of the forcing mechanism

Source: Hansen et al., JGR, **110**, D18104, 2005.

Inefficiencies in fertilizer nitrogen use offer important opportunities for mitigation of nitrous oxide emissions



4% of the N produced in the Haber-Bosch process and used for animal production enters the human mouth.

Galloway JN and Cowling EB. 20

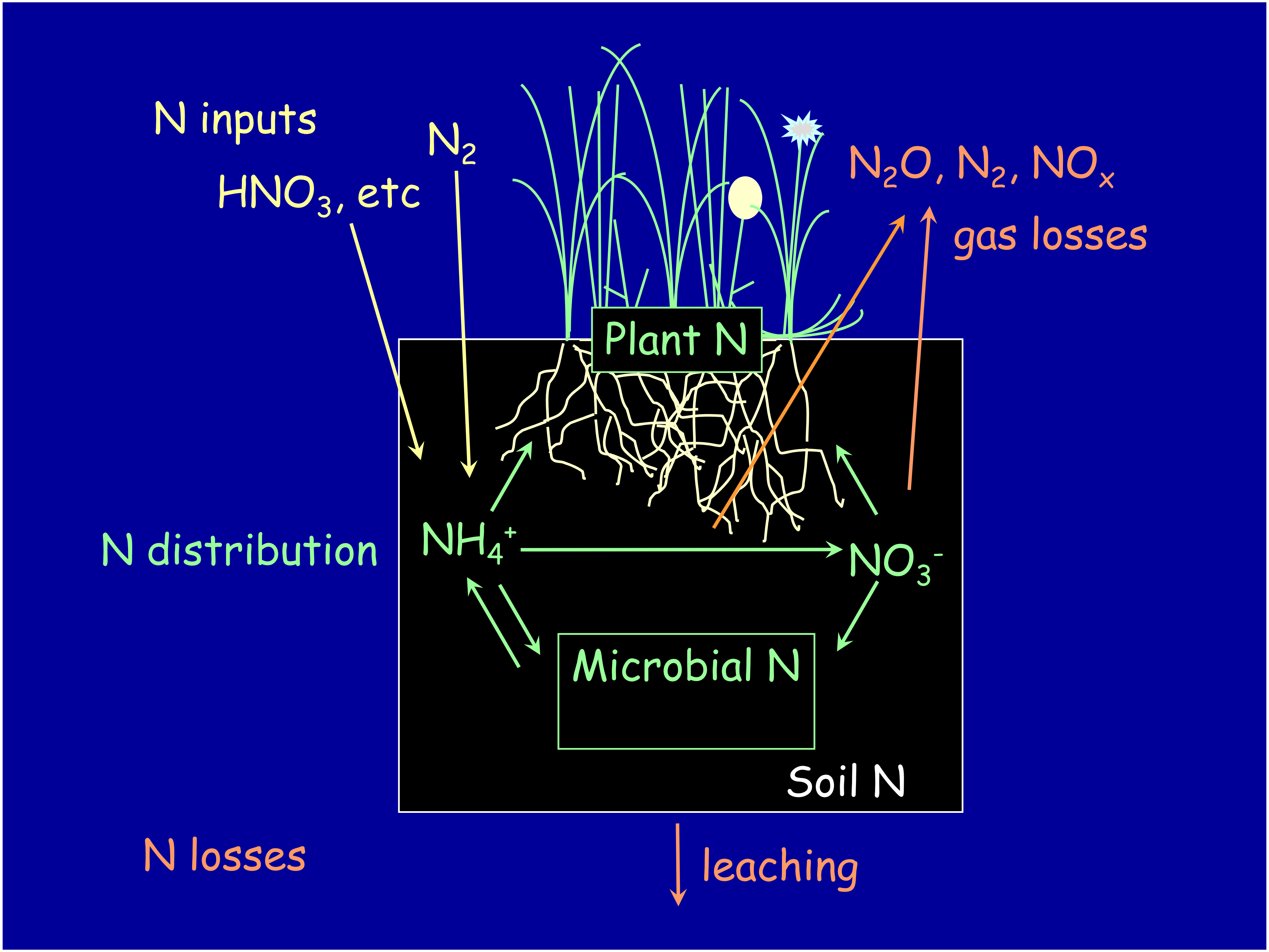
DNDC: A Computer-aided Tool for Precision Land Management

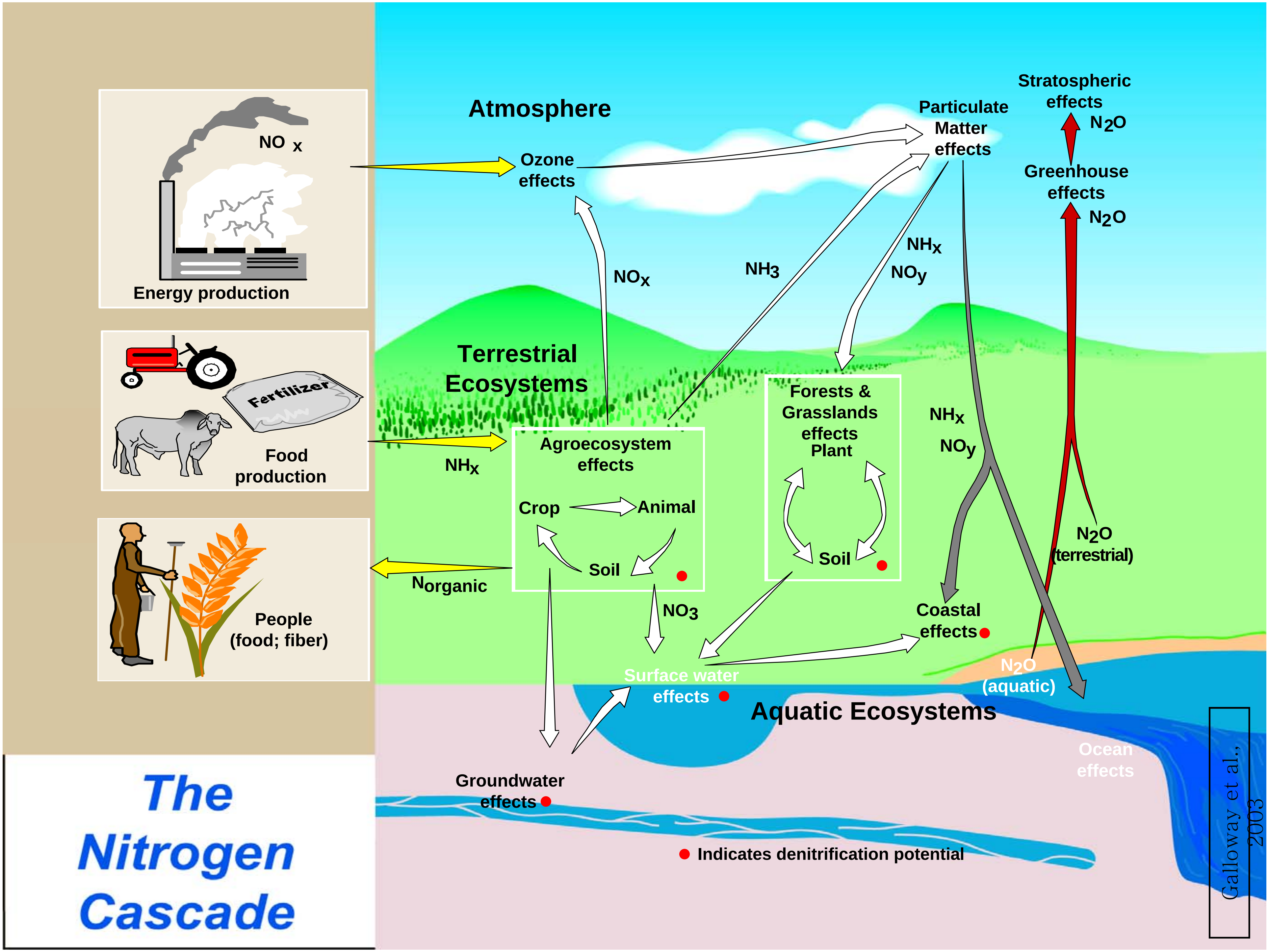
DNDC Reveals the mechanisms that drive ecosystem change by tracking movement of chemical elements between life and its environment

DNDC allows users to construct scenarios that benefit land managers and enhance environmental protection.

DNDC can stimulate innovation and information sharing relevant to creating better landscape management for people and nature

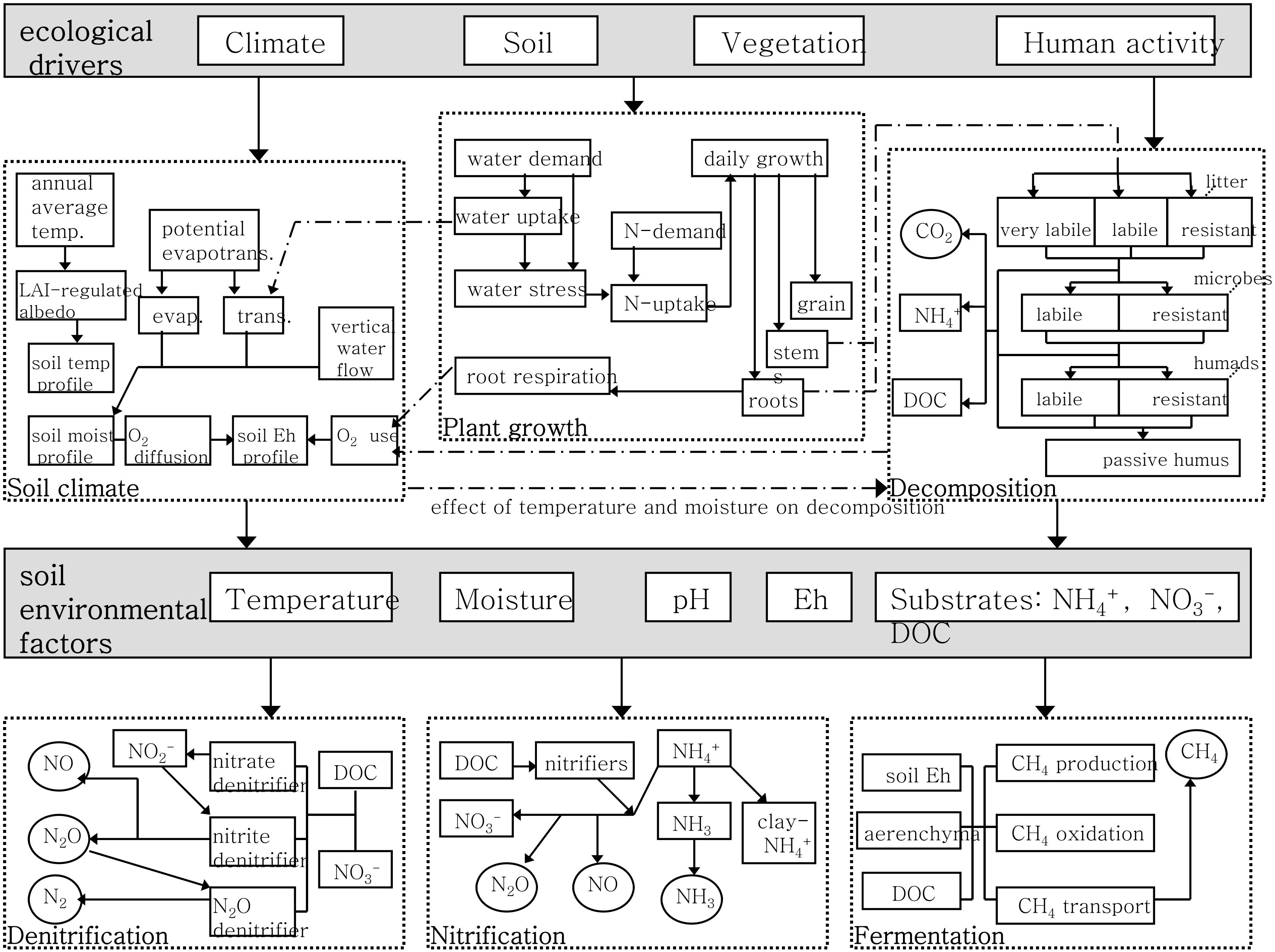

Site Model - dndc7.3
Site Region Exit
Input Run
Input Run
Pause Stop Exit
Welcome to DNDC
http://www.dndc.sr.unh.edu
For Help, press F1
Mouse
Start
Exploring - Dndc
dndc2
Model_C&N_agro
Site Model - dndc7.3
10:24 AM


N inputs
HNO3, etc
N2
N2O, N2, NOx
gas losses
Plant N
N distribution
NH4+
NO3-
Microbial N
Soil N
N losses
leaching

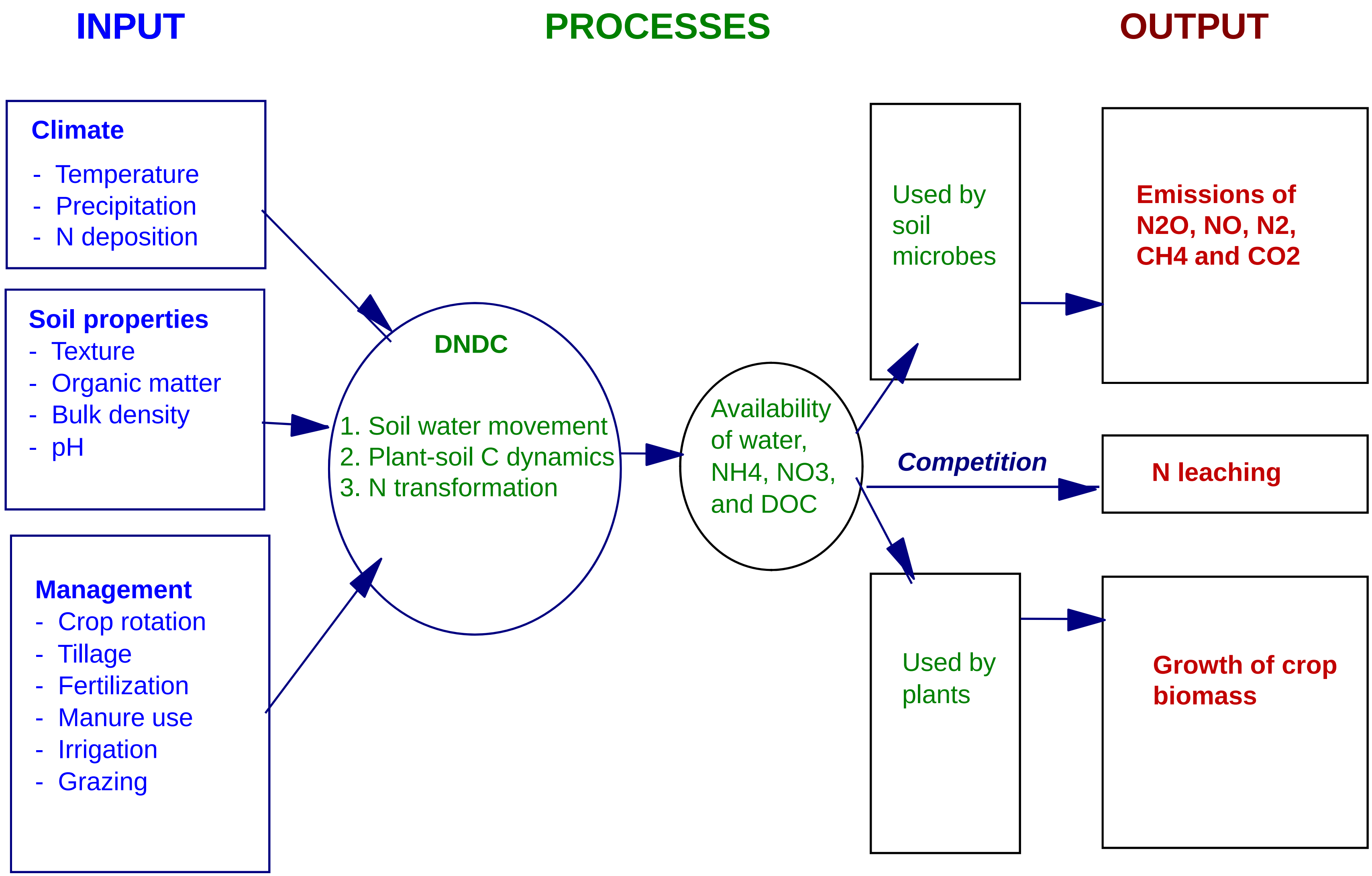


Atmosphere
NO x
Energy production
Ozone effects
Particulate Matter effects
Stratospheric effects
N2O
Greenhouse effects
N2O
NOx
NH3
NHx
NOy
Fertilizer
Food production
Terrestrial Ecosystems
NHx
Agroecosystem effects
Crop
Animal
Soil
Forests & Grasslands effects
Plant
Soil
NHx
NOy
N2O (terrestrial)
People (food; fiber)
Norganic
NO3
Coastal effects
Surface water effects
N2O (aquatic)
Aquatic Ecosystems
Ocean effects
Groundwater effects
Indicates denitrification potential
The Nitrogen Cascade
Galloway et al., 2003

The DNDC Model

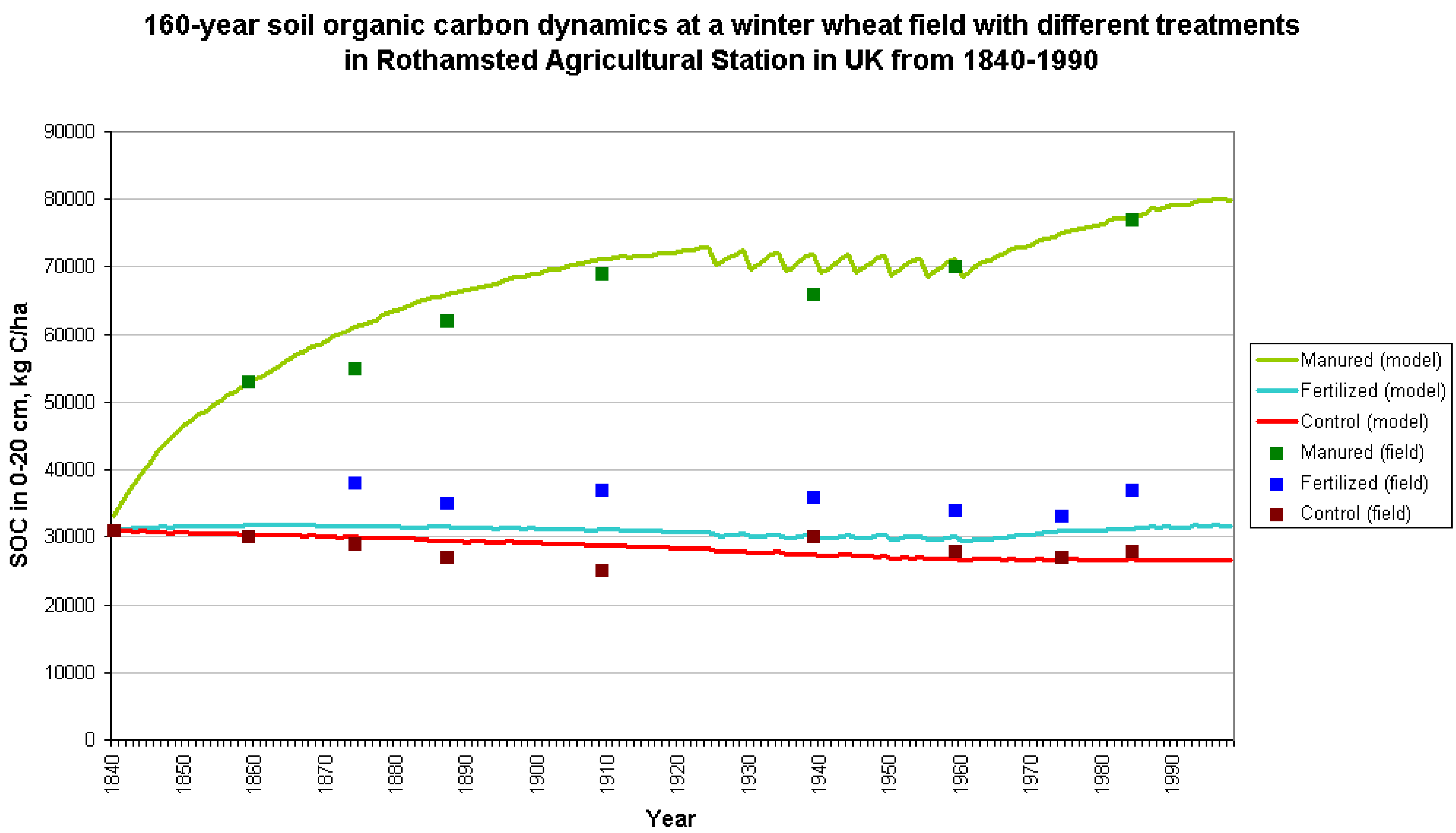


DNDC bridges between inputs and outputs

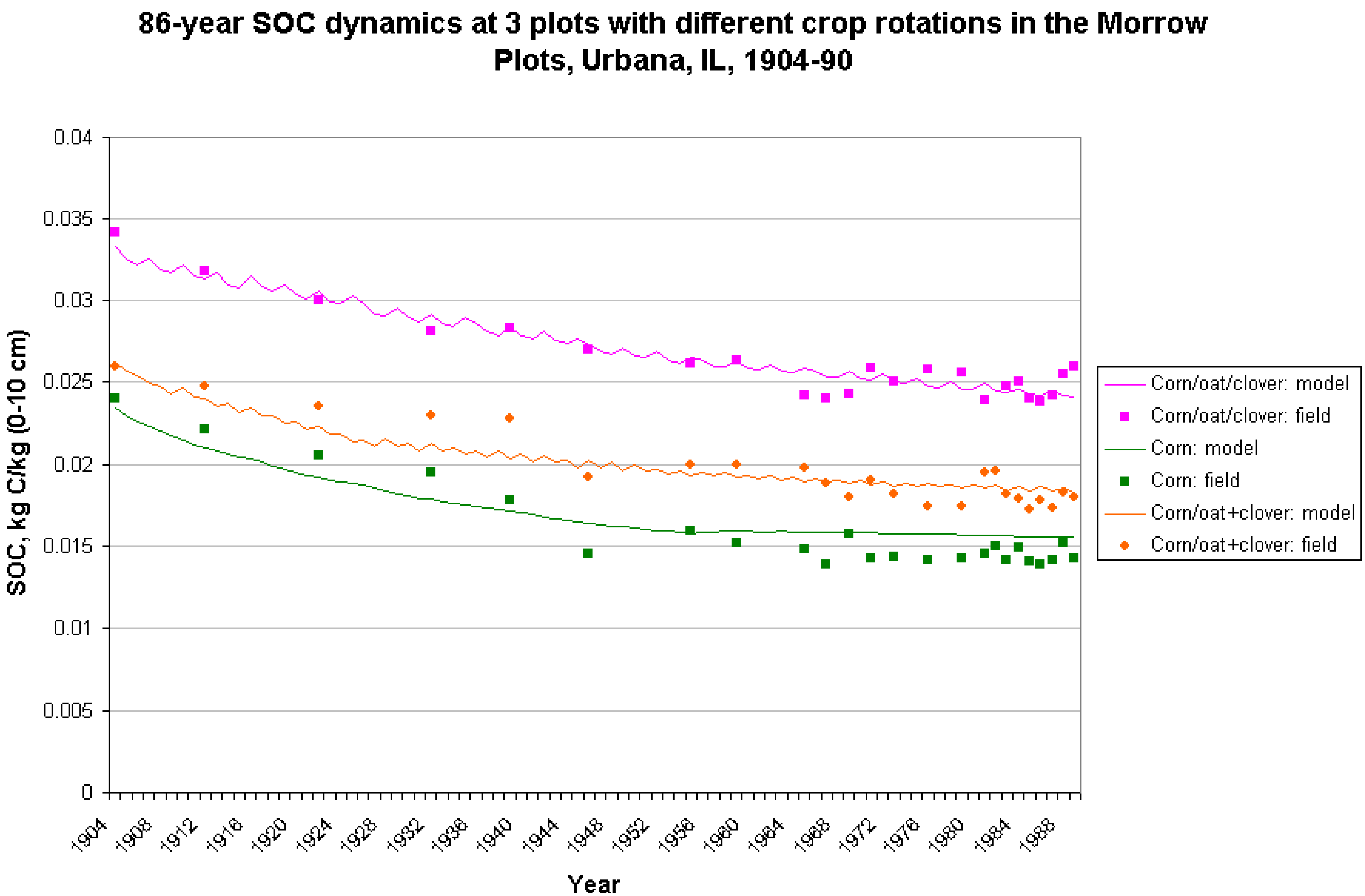


DNDC

Simulating carbon in soils and ecosystems

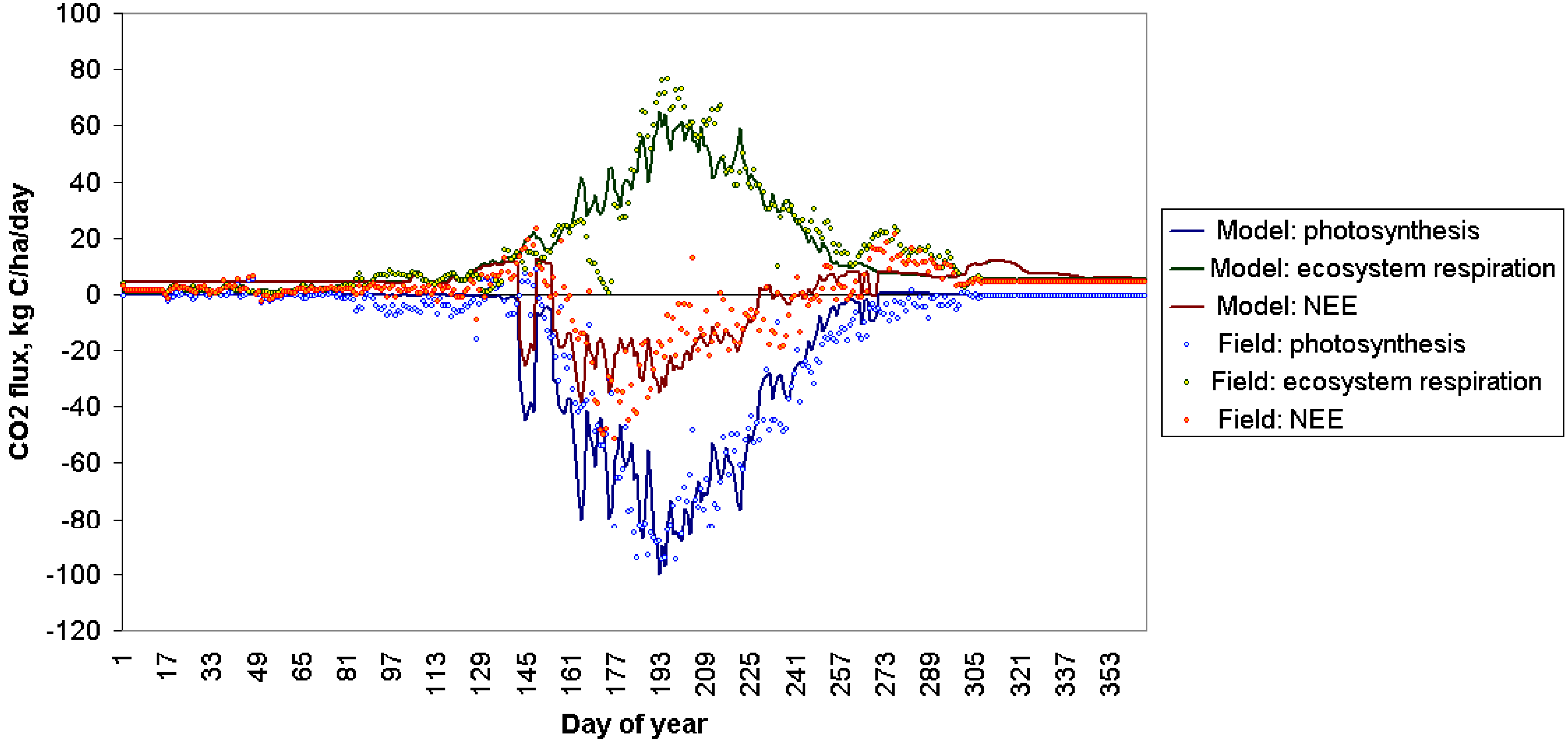


160-year soil organic carbon dynamics at a winter wheat field with different treatments
in Rothamsted Agricultural Station in UK from 1840-1990
SOC in 0-20 cm, kg C/ha
Year
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Manured (model)
Fertilized (model)
Control (model)
Manured (field)
Fertilized (field)
Control (field)


86-year SOC dynamics at 3 plots with different crop rotations in the Morrow Plots, Urbana, IL, 1904-90
SOC, kg C/kg (0-10 cm)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1904
1908
1912
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
Year
Corn/oat/clover: model
Corn/oat/clover: field
Corn: model
Corn: field
Corn/oat+clover: model
Corn/oat+clover: field

Model performance can be tested based on short- or long-term observations on C fluxes

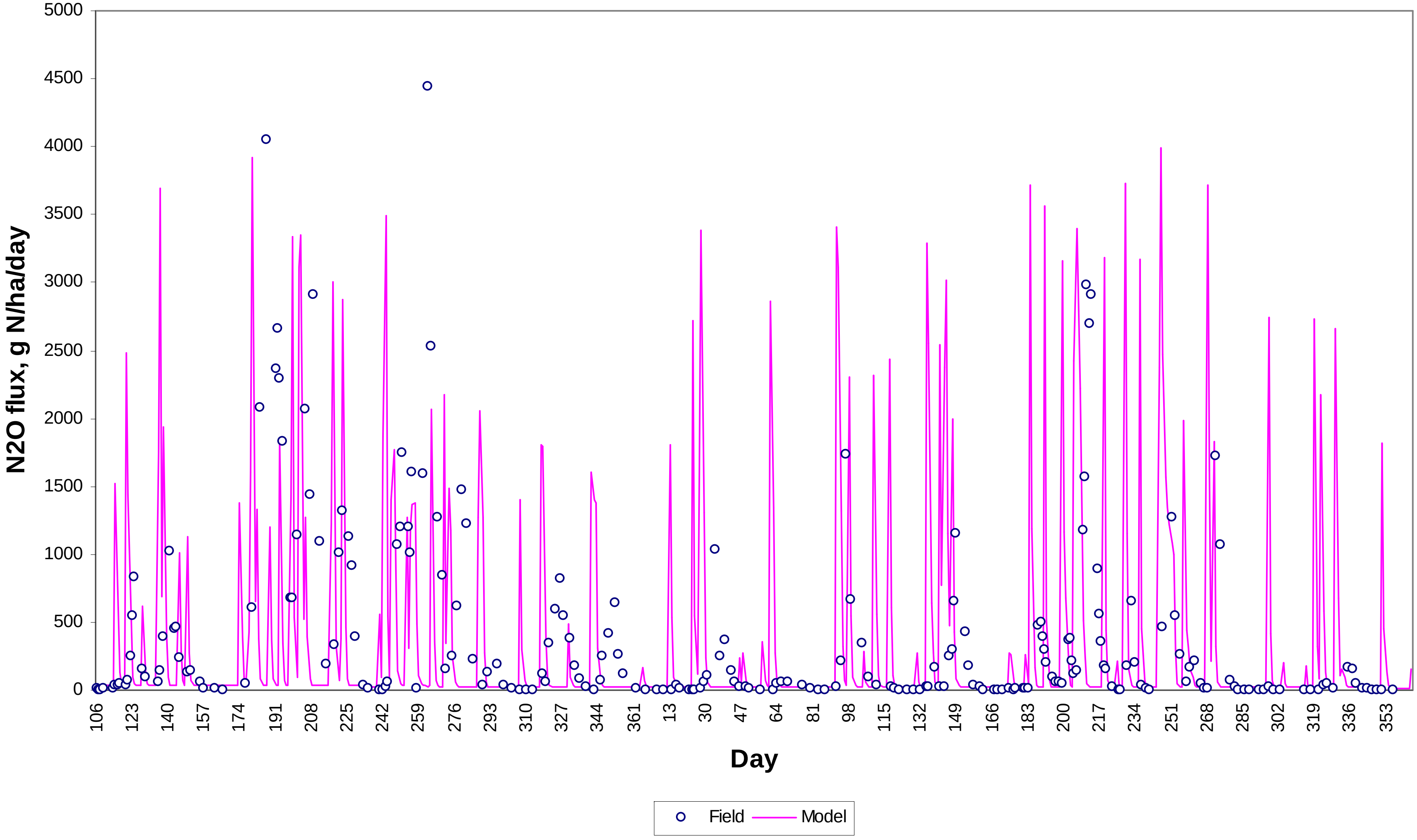
Observed and DNDC-modeled photosynthesis, ecosystem respiration and NEE fluxes from a cultivated peat soil in Linnansuo, Finland in 2005



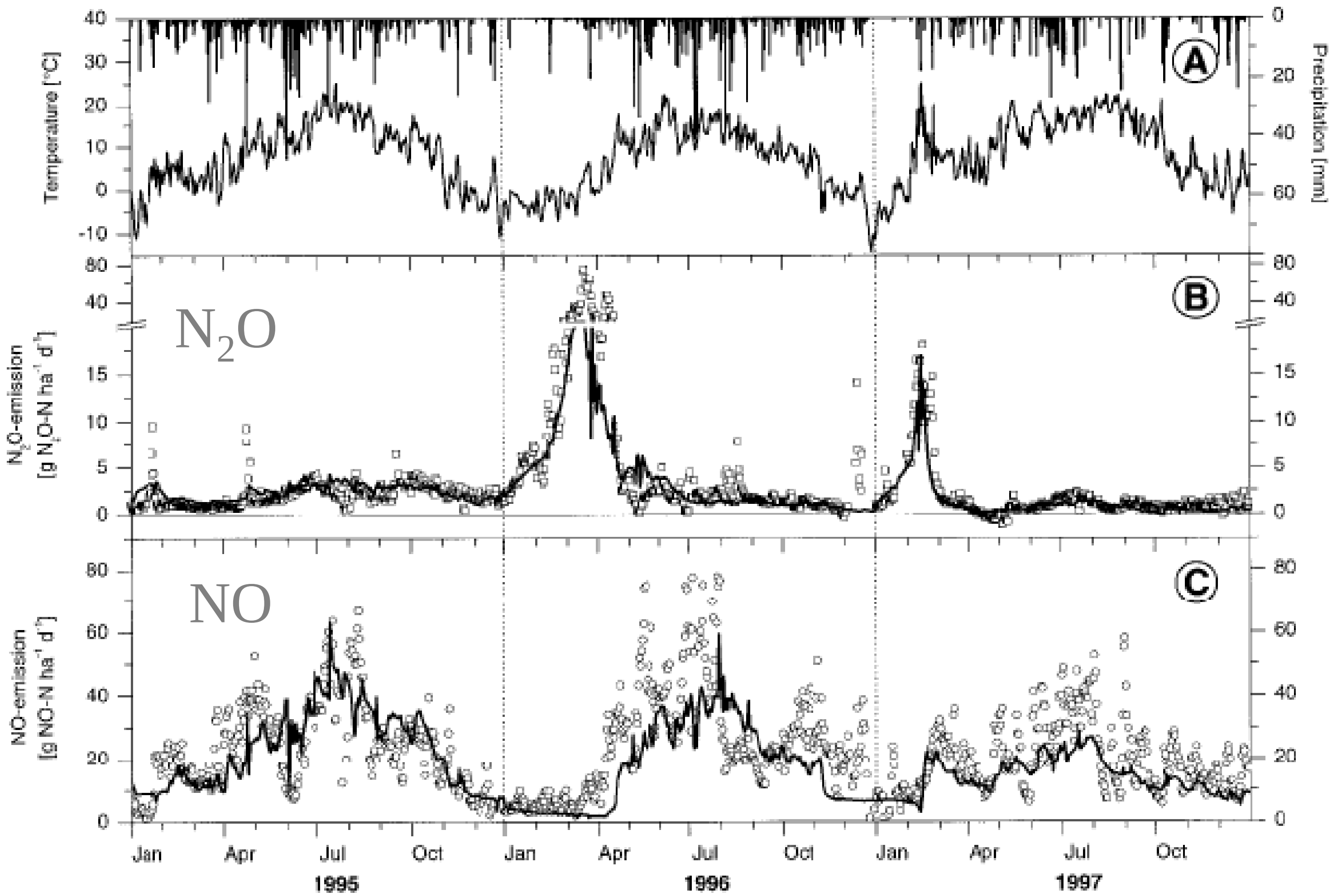
DNDC

Simulating nitrogen in soils and ecosystems

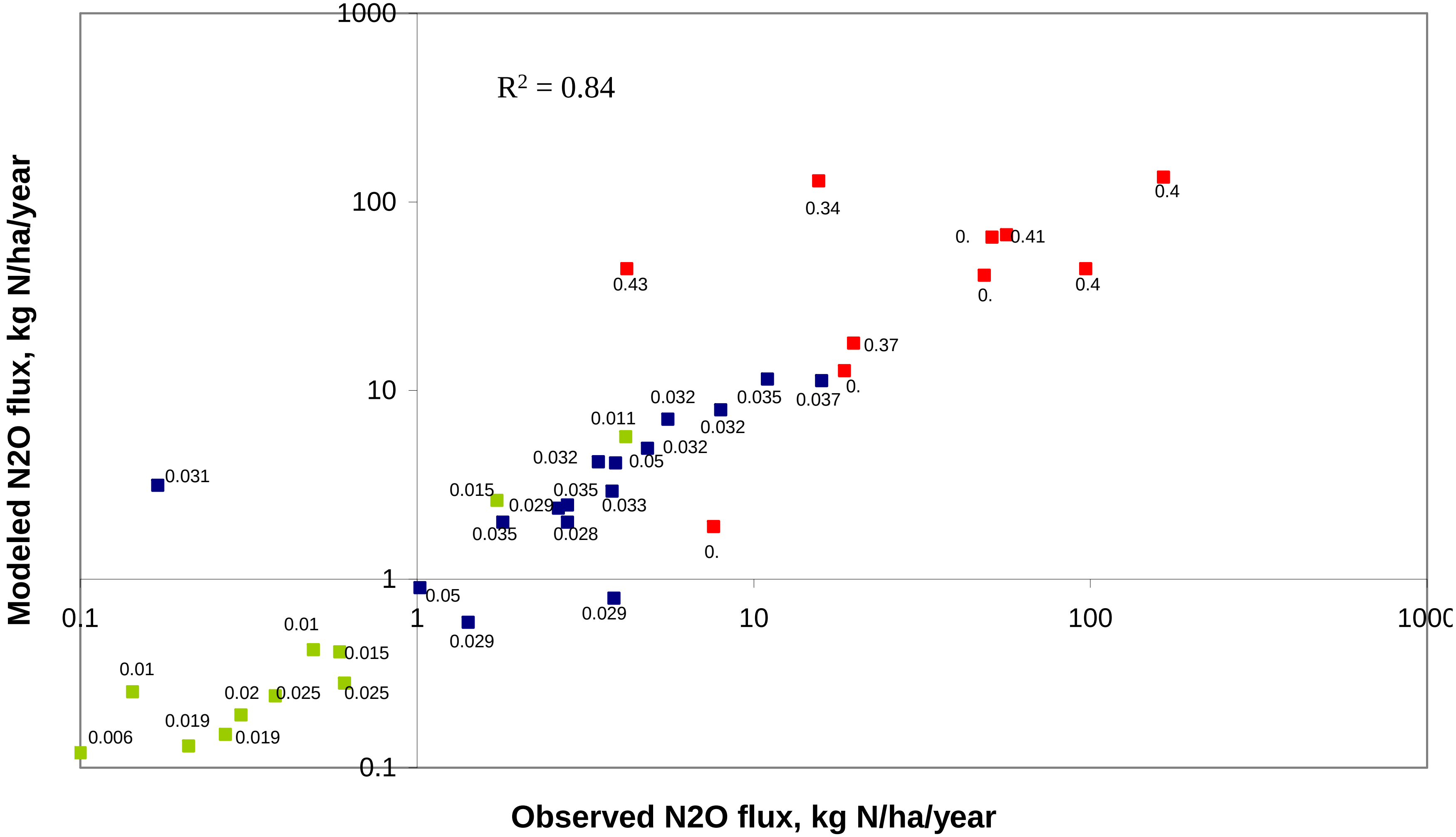
N2O Fluxes from a Organic Soil at Glades, Florida, 1979-80



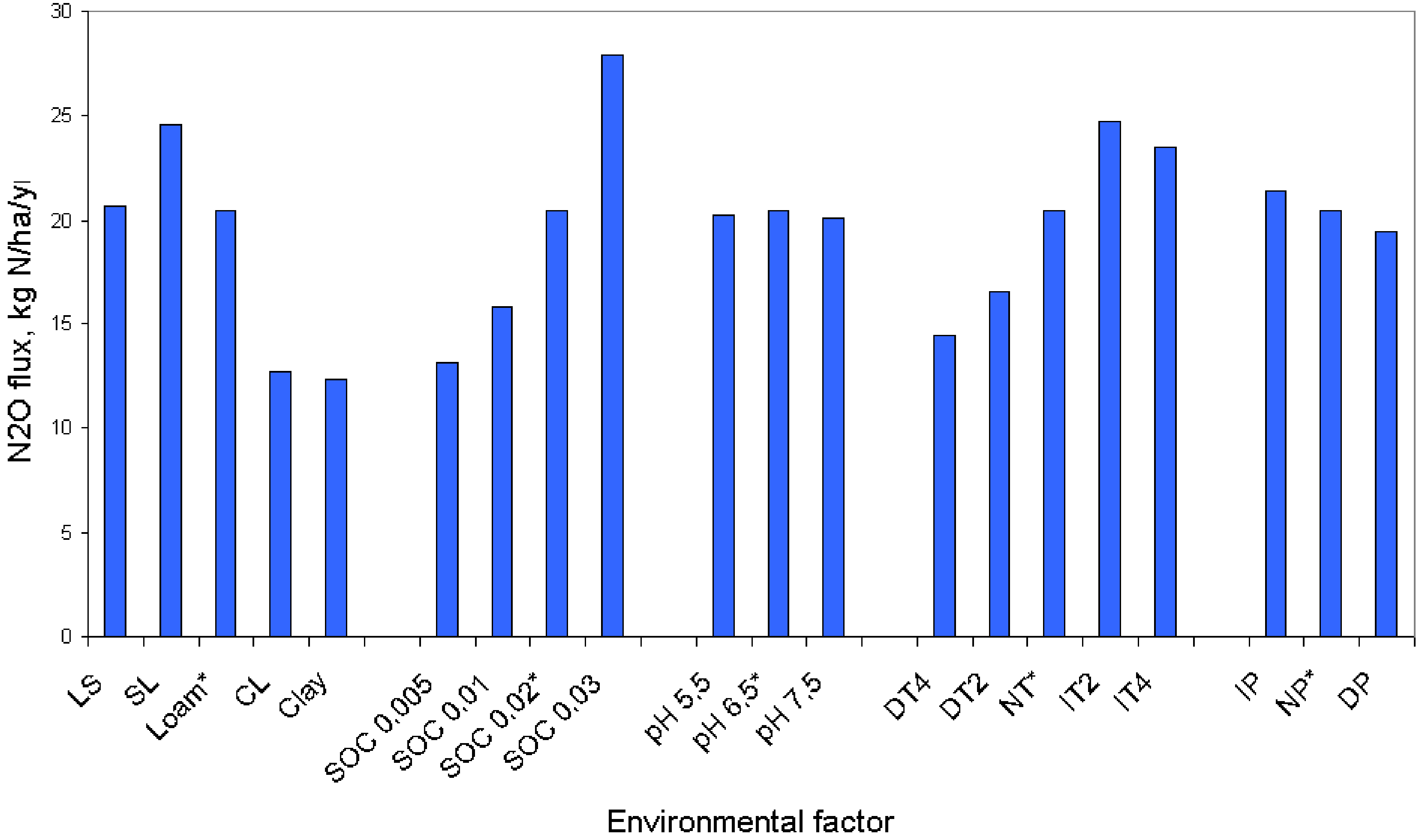
Observed and Modeled N_2O and NO Emissions from a Spruce Stand at Hoglwald Forest in Germany in 1995-1997



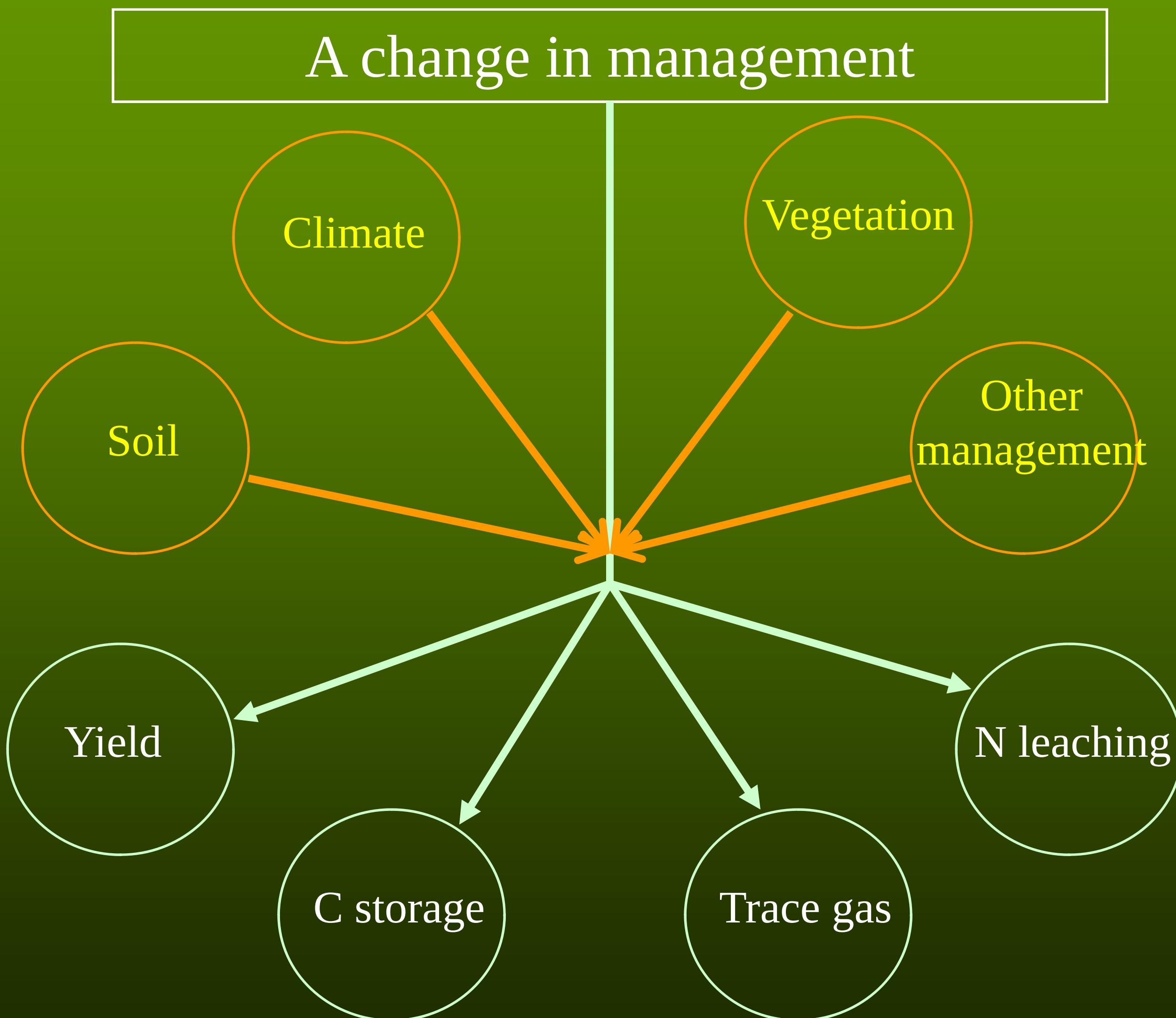
Observed and DNDC-Modeled N2O Fluxes from Agricultural Soils in the U.S., Canada, the U.K., Germany, New Zealand, China, Japan, and Costa Rica



Sensitivity of N_2O flux to environmental factors



Goal: Predicting impacts of management alternatives on C and N dynamics in terrestrial ecosystems



A scenario of best management practices was composed with

(1) no-till,
(1) increased depth of fertilizer application,
(3) three splits of fertilizer application, and
(4) non-legume cover crop.

Impacts of conventional tillage (CT), no-till (NT) and best management practices (BMP) for a crop field at Story County, Iowa

	CT	NT	BMP	Unit
Fertilizer use	120	120	120	kg N/ha
Crop yield	4188	3830	4138	kg C/ha
dSOC	-86	415	996	kg C/ha
N leaching	47	20	8	kg N/ha
N2O	19	28	16	kg N/ha

Summary

- Precision management of fertilizer use can provide significant reductions in nitrous oxide emissions while maintaining crop yields. Co-benefits can include reductions in water pollution that results from leaching of nitrate.
- Soil carbon and nitrogen must be treated as an integrated management issue to achieve maximum benefits.
- The DNDC precision management tool can also be applied to the management of timber, pastures, rice, and other landscapes.
- A market-based fertilizer reduction program could offer a fast-track approach to reductions in nitrous oxide emissions and nitrate pollution.

Summary

Uncertainties, unclear signals, and long time scales are characteristic of climate, water, and ecosystem interactions. We argue that there is a strong rationale for enhanced policy flexibility and innovation using a portfolio of reactive, adaptive, and precautionary land management strategies.