Potential Quantities and Regional Distribution of N_2O Emissions Reductions Associated with Changing N Fertilizer Management Practices

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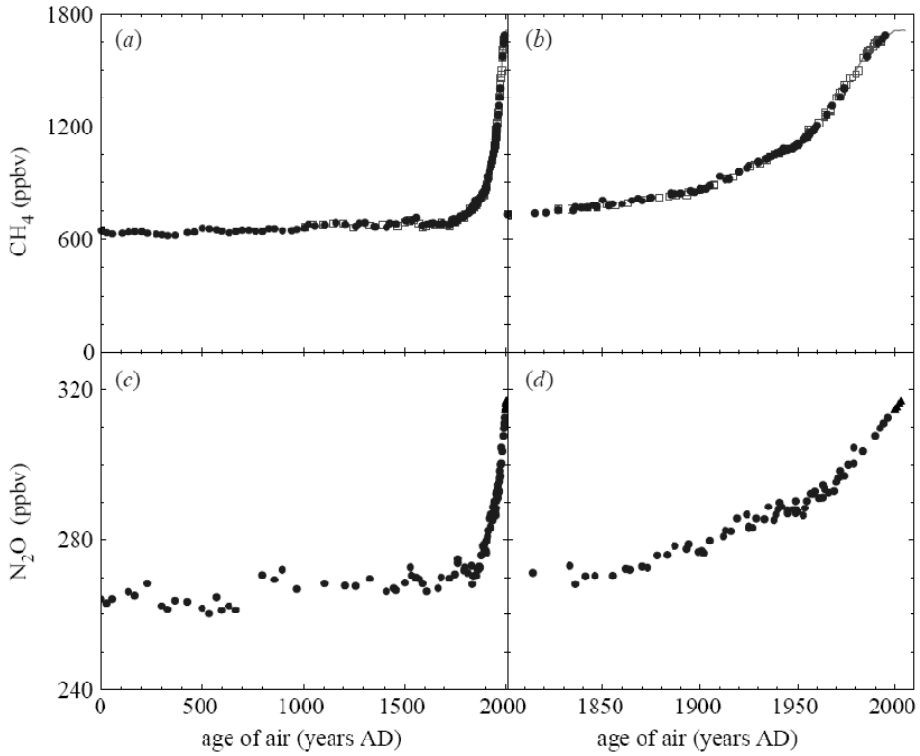
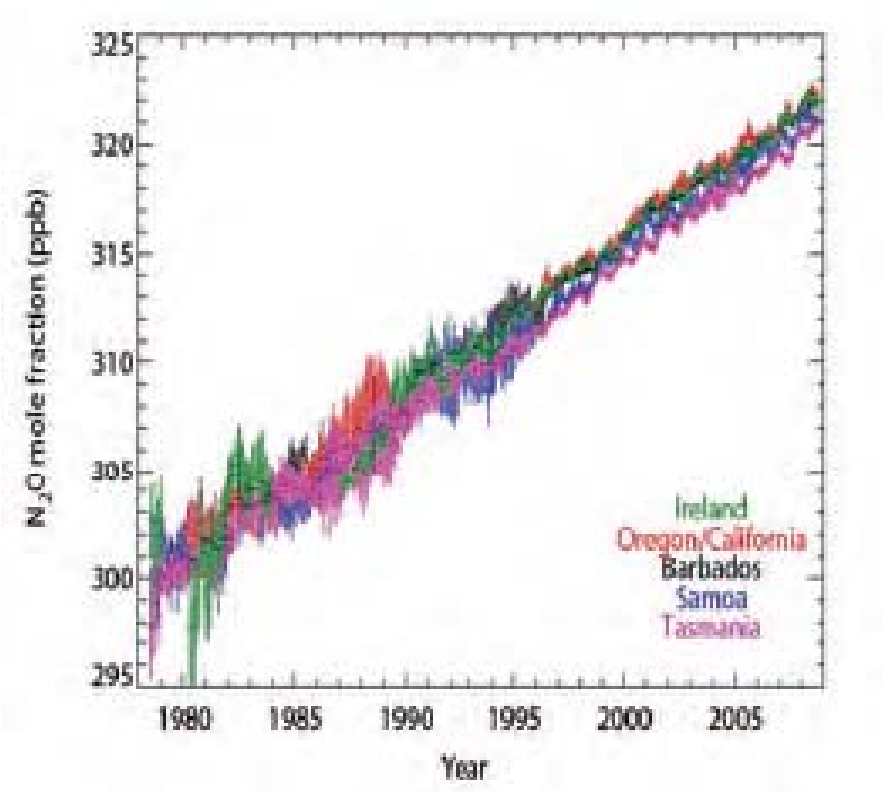
Presentation Outline

- Global atmospheric N_2O and Global Agricultural N
- General guidelines
- Where & in what crops is fertilizer N used in the US
- Where could efforts to decrease N input be focused
- Mechanisms of increasing fertilizer N use efficiency
- How much could N use be decreased
- How much N_2O is actually released from new reactive N input

The global atmosphere





For thousands of years the N_2O concentration in Earth's atmosphere was constant (sources = sinks).

The recent increase in concentration = excess of global emissions over the N_2O sinks, driven by increases in the amount of reactive N entering the environment.

Annual Increase of Atmospheric N_2O

Atmospheric Growth Rate is 0.75 ppbv/yr: ~ 4 Tg N each year

Atmospheric Lifetime is ~ 100 years

Annual anthropogenic N_2O to atmosphere: ~ 6 Tg N

~ 70% of anthropogenic N_2O is produced from new N input for Food Production

IPCC, 2001, 2007; Crutzen et al. 2008; Smith et al. 2010

General Guidelines

- N_2O emissions resulting from crop production are ultimately related to total N input. In the long term , N_2O reductions can be made only by decreasing N input by increasing N use efficiency

- Consider all N inputs (e.g. crop residue, livestock waste, residual soil mineral N, legume crops)

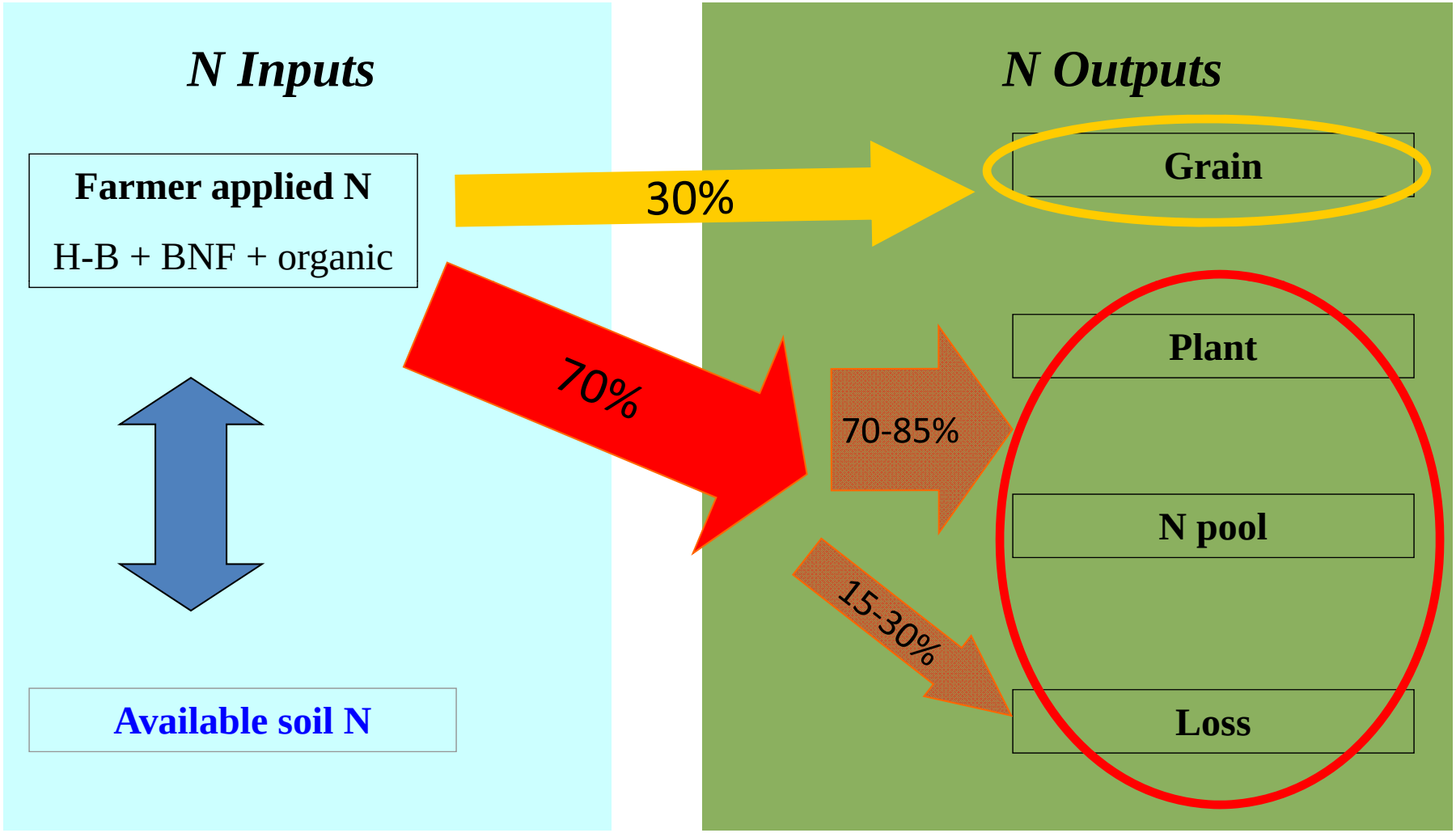
- Need to consider all N species (ammonia, nitrate, NO_x, N_2O) and soil C so that N-species pollution swapping doesn't occur

Nitrous Oxide is the main greenhouse gas emitted from soils that is directly related to crop production in the USA

N_2O is mainly produced by microbial processes in the soil and is emitted:

- **Directly from the field during crop production**
- **Indirectly from N leached, volatilized or eroded from fields**
- **From livestock production and waste management**

Crop N cycling



Burke et al. 2005. Consequences of Industrialized Animal Production

References

N Use & Management in the USA

Nitrogen in Agricultural Systems: Implications for Conservation Policy
M. Ribaudo, J. Delgado, L. Hansen, M. Livingston, R. Mosheim & J. Wiliamson
USDA/ERS Report # 127, September 2011

Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, consequences and Management Options. A report of the EPA Science Advisory Board, EPA-SAB-11-013, August 2011

Global N_2O

The Global Nitrous Oxide Budget: A Reassessment
K. Smith, P. Crutzen, A. Mosier & W. Winiwarter
In: Nitrous Oxide and Climate Change, Keith Smith (ed.), 2010

How Much N? N Fertilizer Used in major crops in the USA in 2006 (ERS, 2011; IFA; EPA))

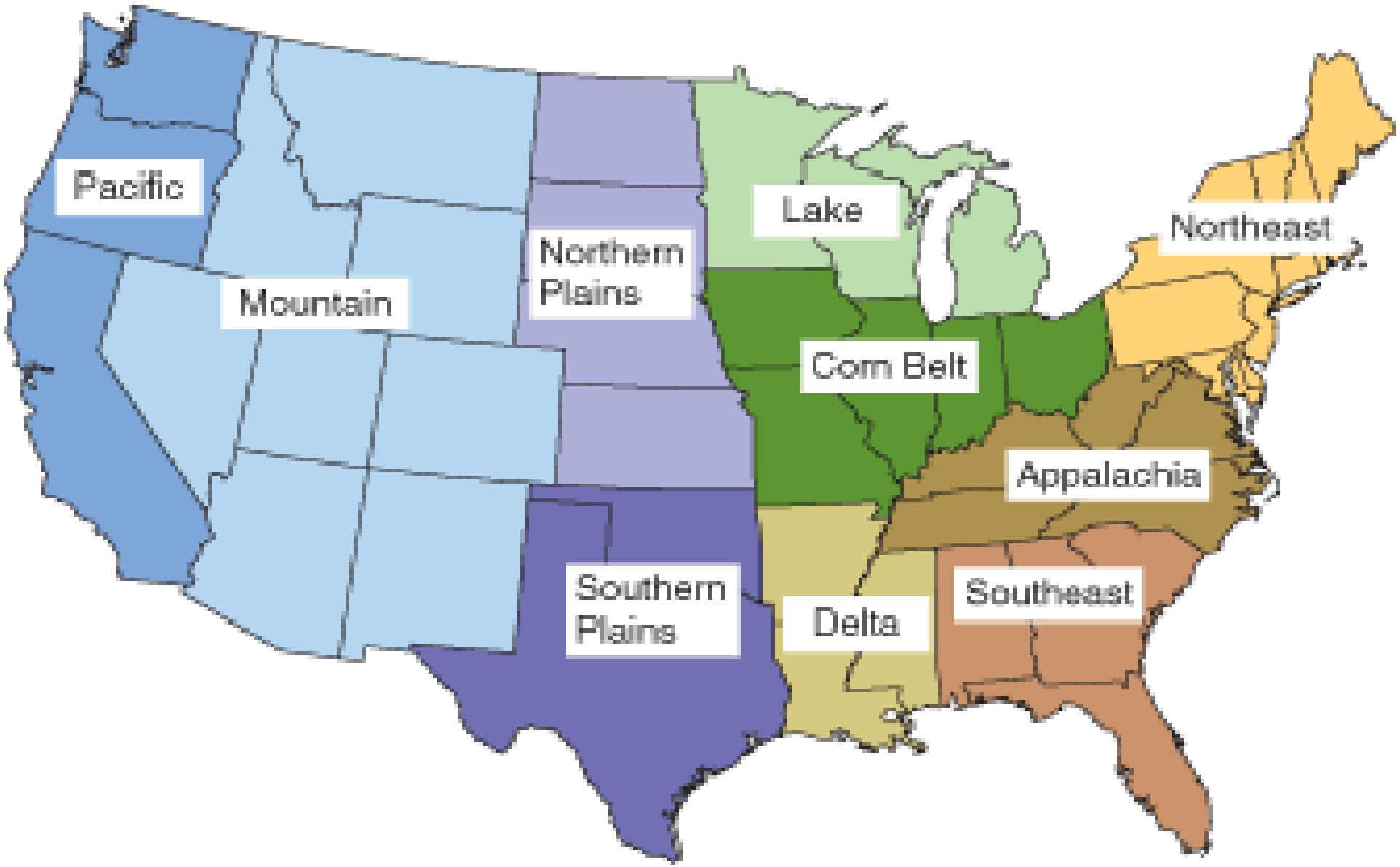
Total N	**13.1 synthetic + ~ 1.3 livestock manure (million U.S. ton)**
Applied to:	
Barley	**0.1**
Corn	**5.8**
Cotton	**0.6**
Oats	**0.1**
Peanuts	**0.01**
Sorghum	**0.22**
Soybeans	**0.25**
Wheat	**1.77**
Total	**8.8 applied to these 8 crops**

Where was the remaining 5.6 million tons applied?

~1.3 million tons was applied to turf grass (EPA, 2011)

Vegetable production uses high rates of N

Figure 3.3
USDA farm production regions



Source: USDA, Economic Research Service.

USDA/ERS, 2011 Report

N-Fertilization Criteria: Rate/Timing/Method

Rate: No more N (synthetic or manure) than 40% more than removed with the crop at harvest.

Timing: Not applying N in fall for a spring-planted crop

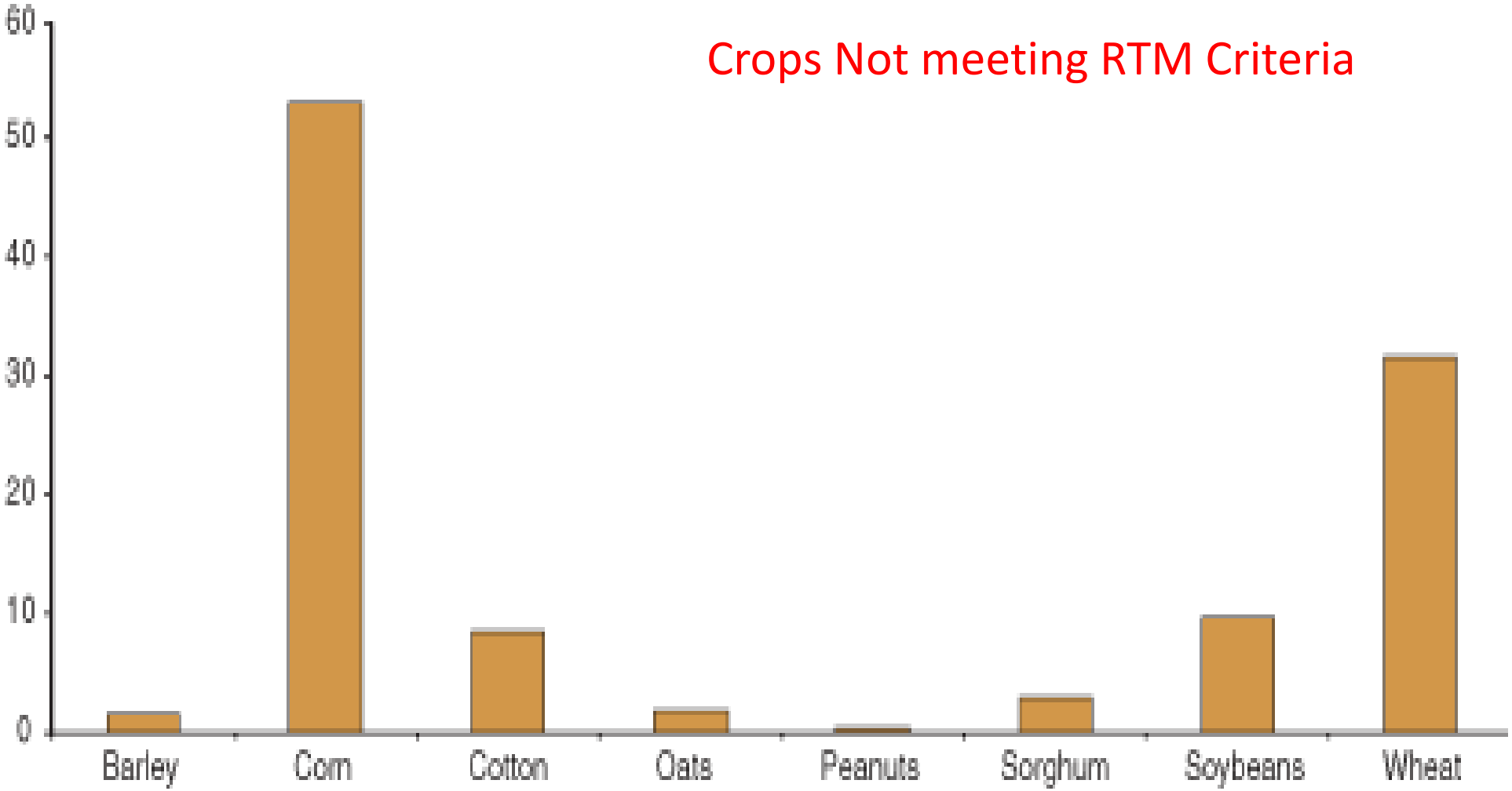
Method: Injecting or incorporating N rather than broadcasting without incorporation.

****MRTN—maximum return to N: The N rate where the economic net return to N application is maximized**

Figure 3.1

Acres treated with commercial and/or manure nitrogen not using nitrogen best management practices, 2006

Million treated acres

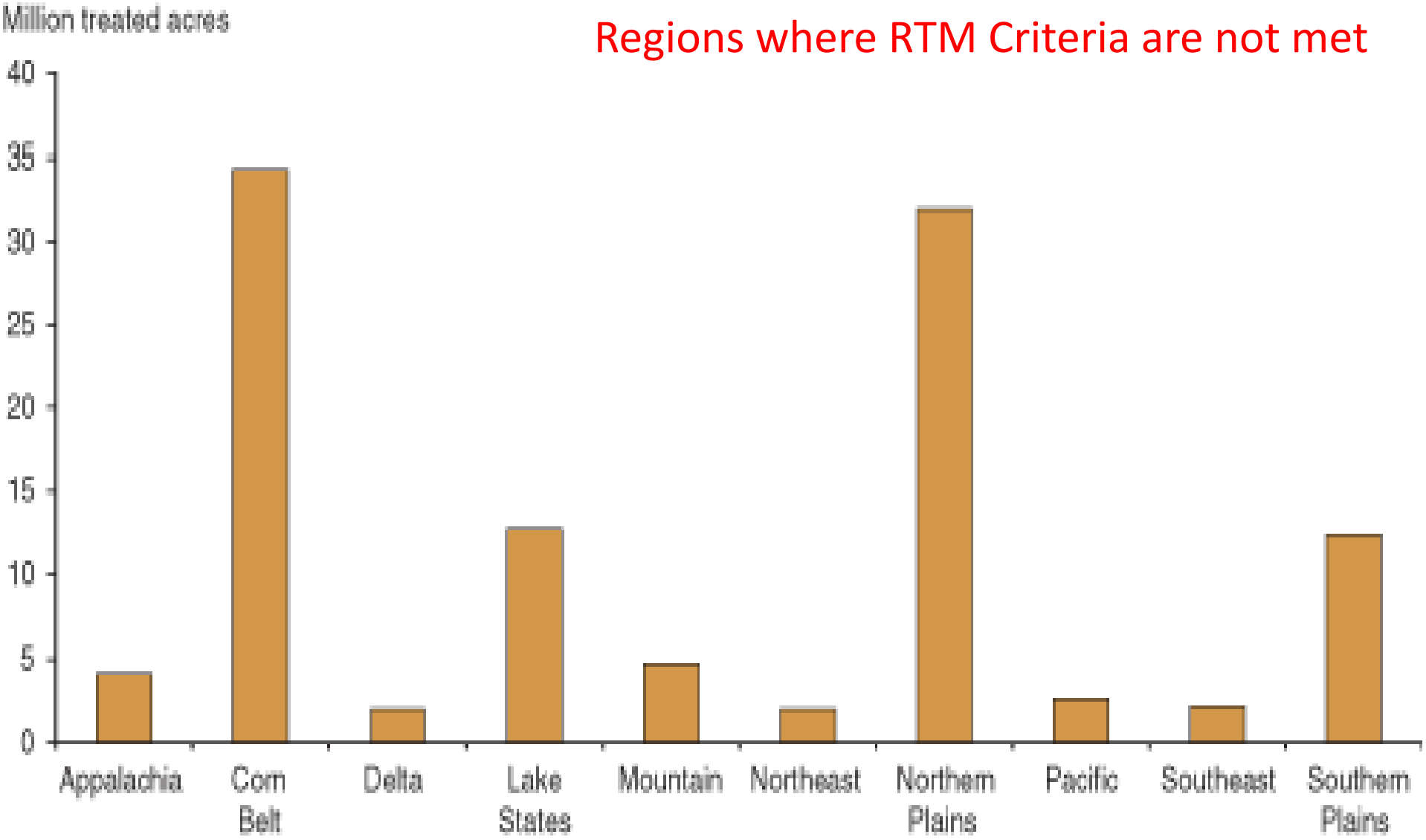


Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

Figure 3.2

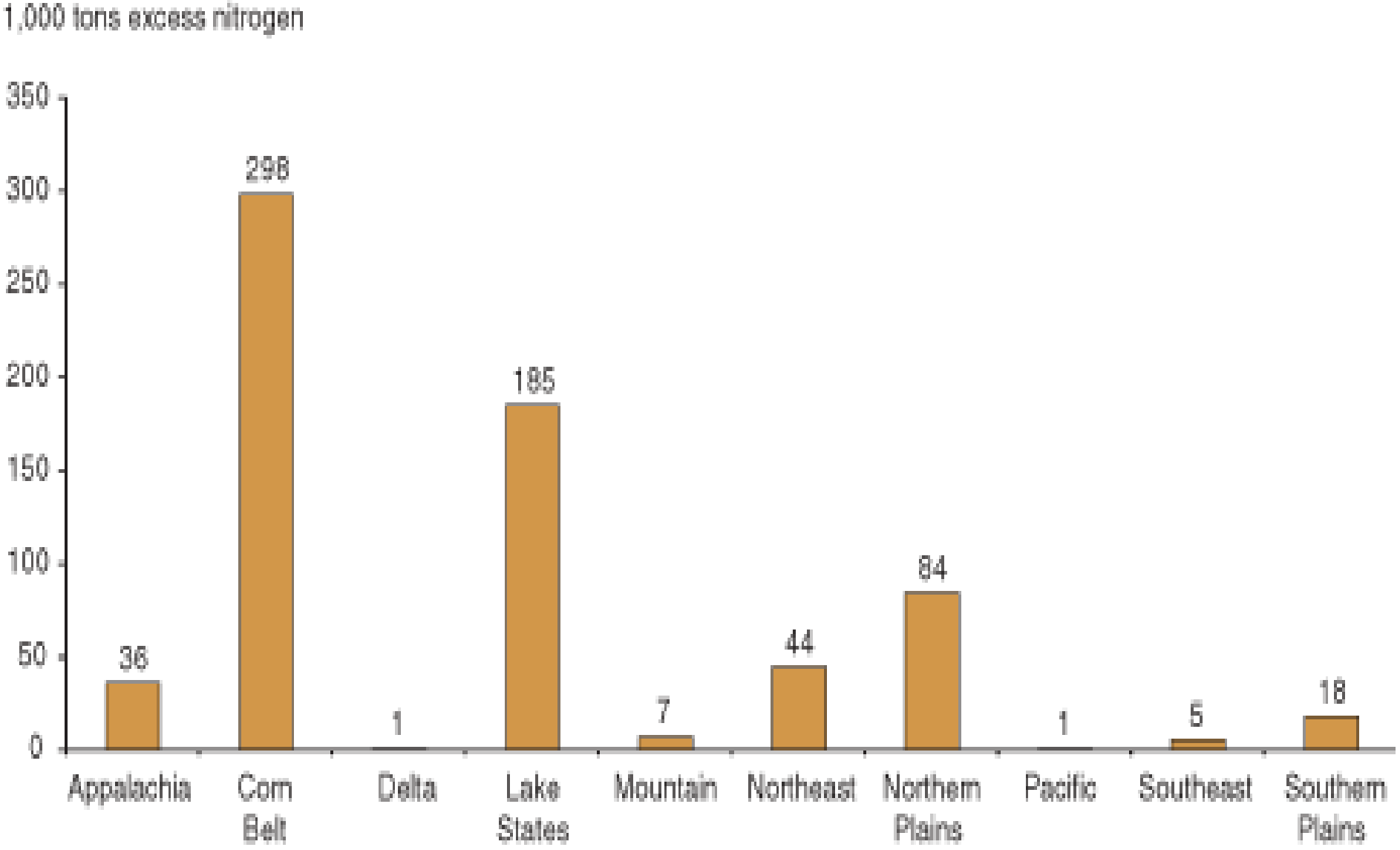
Acres treated with commercial and/or manure nitrogen not using nitrogen best management practices, by region, 2006

Regions where RTM Criteria are not met



Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II.
See table 3.1 for details.

Total nitrogen applications above criterion rate by region, 2006



Note: Criterion rate defined as nitrogen removed at harvest plus 40 percent.
Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

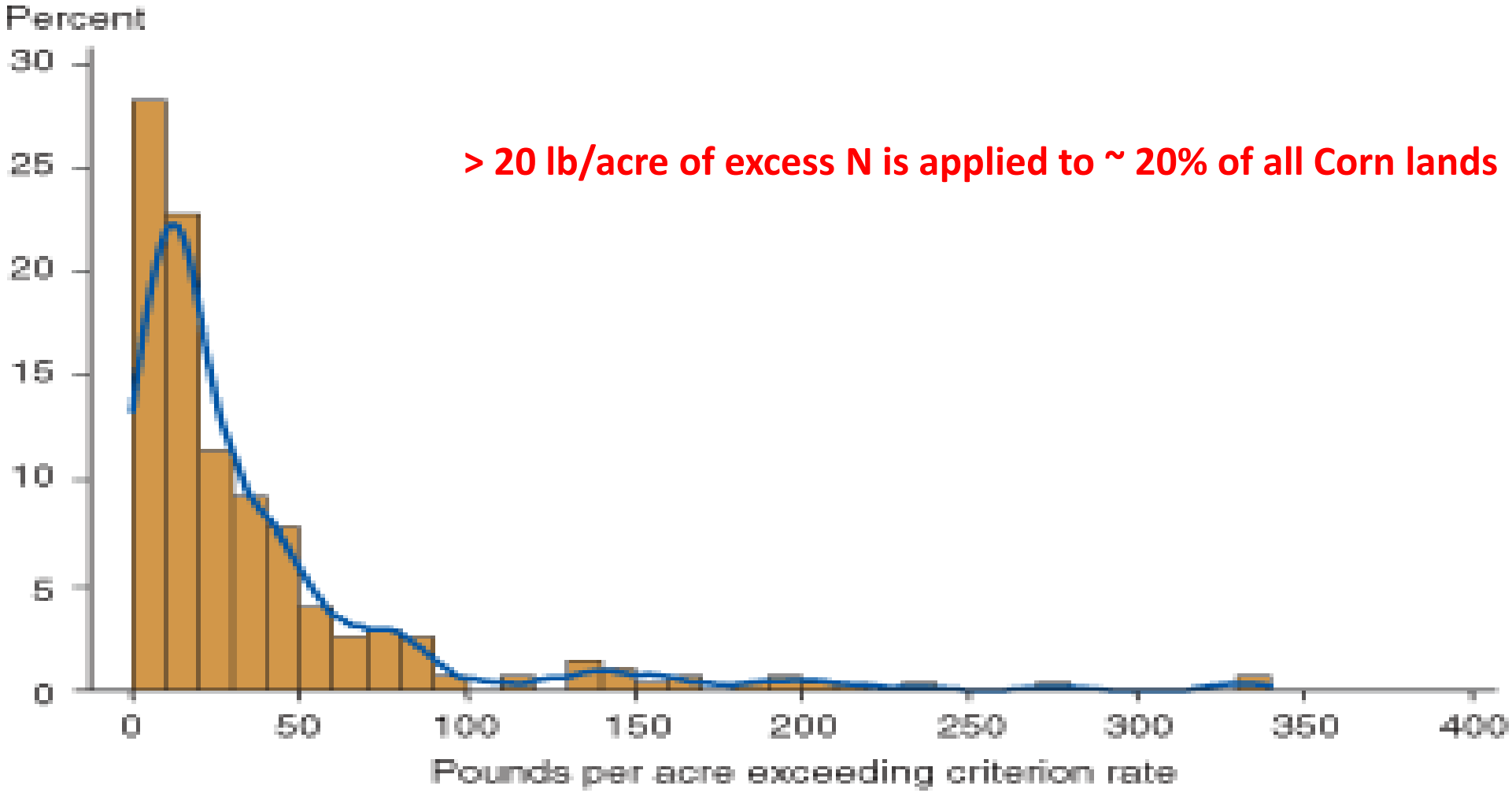
USDA/ERS, 2011 Report

Best Management Practices are frequently not used:

N-Fertilization Criteria: Rate/Timing/Method

- **Rate Criteria not met on 32% of corn acres and 47% of cotton acres (~ 50% of total due to corn)**
- **Timing Criteria not met for 24% of all acres: 34% of corn was fall fertilized!!**
- **Method Criteria not met in 37% of acres (about half in corn)**

Distribution of nitrogen fertilizer applied to corn that exceeded the criterion rate,[1] 2005



> 20 lb/acre of excess N is applied to ~ 20% of all Corn lands

[1]Criterion rate defined as nitrogen removed at harvest plus 40 percent, based on the farmer-stated yield goal.

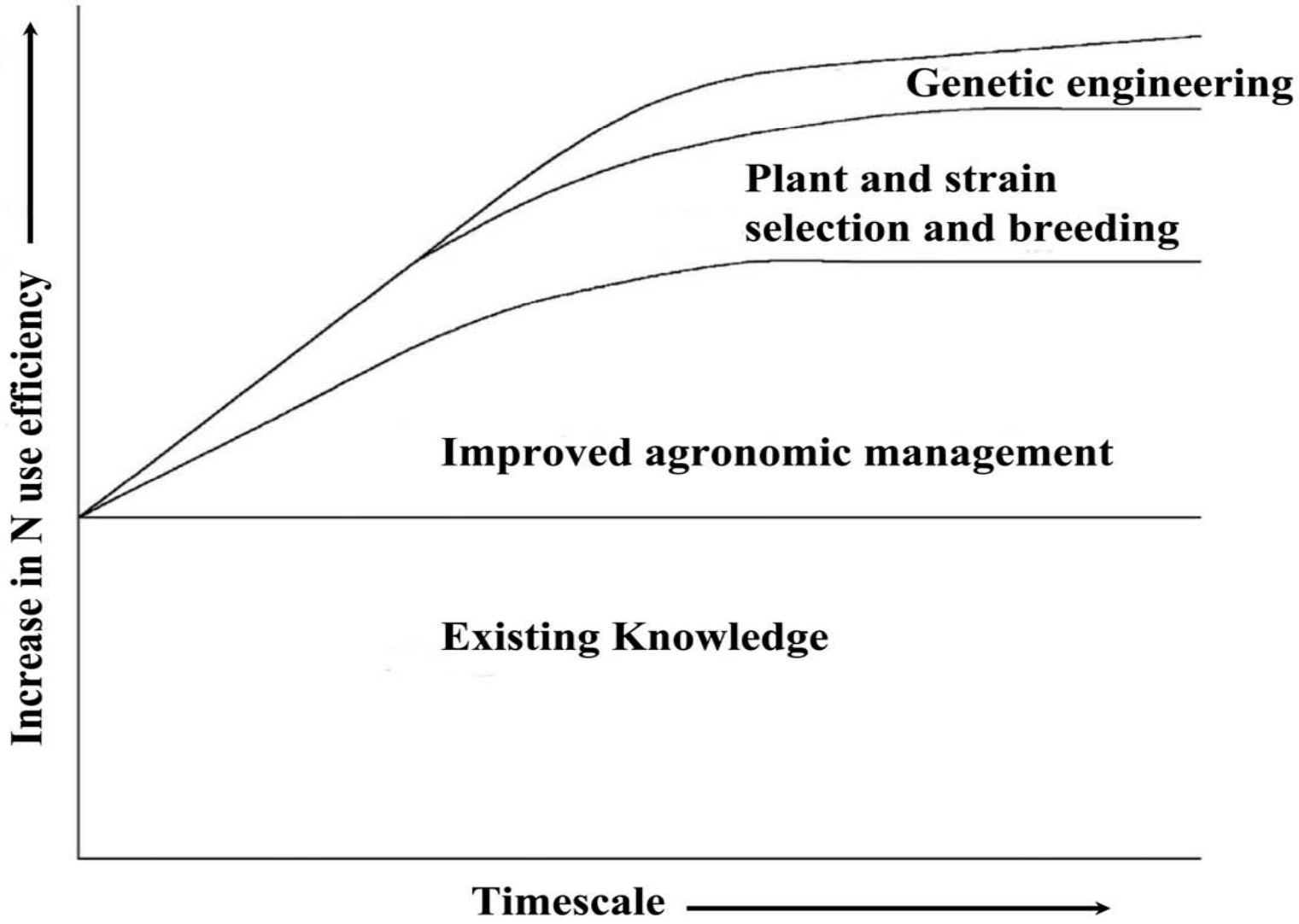
Note: The kernel density, represented by the smooth line, is an estimate of the continuous density using an Epanechnikov kernel.

Source: USDA, Economic Research Service using USDA's 2005 Agricultural Resource Management Survey.

How do we minimize N_2O emissions without decreasing crop yield or increasing ammonia volatilization or nitrate leaching?

Decrease N input by improving N use efficiency

Prospects for Improving N Use Efficiency (SCOPE 65, Fig. 3.2)



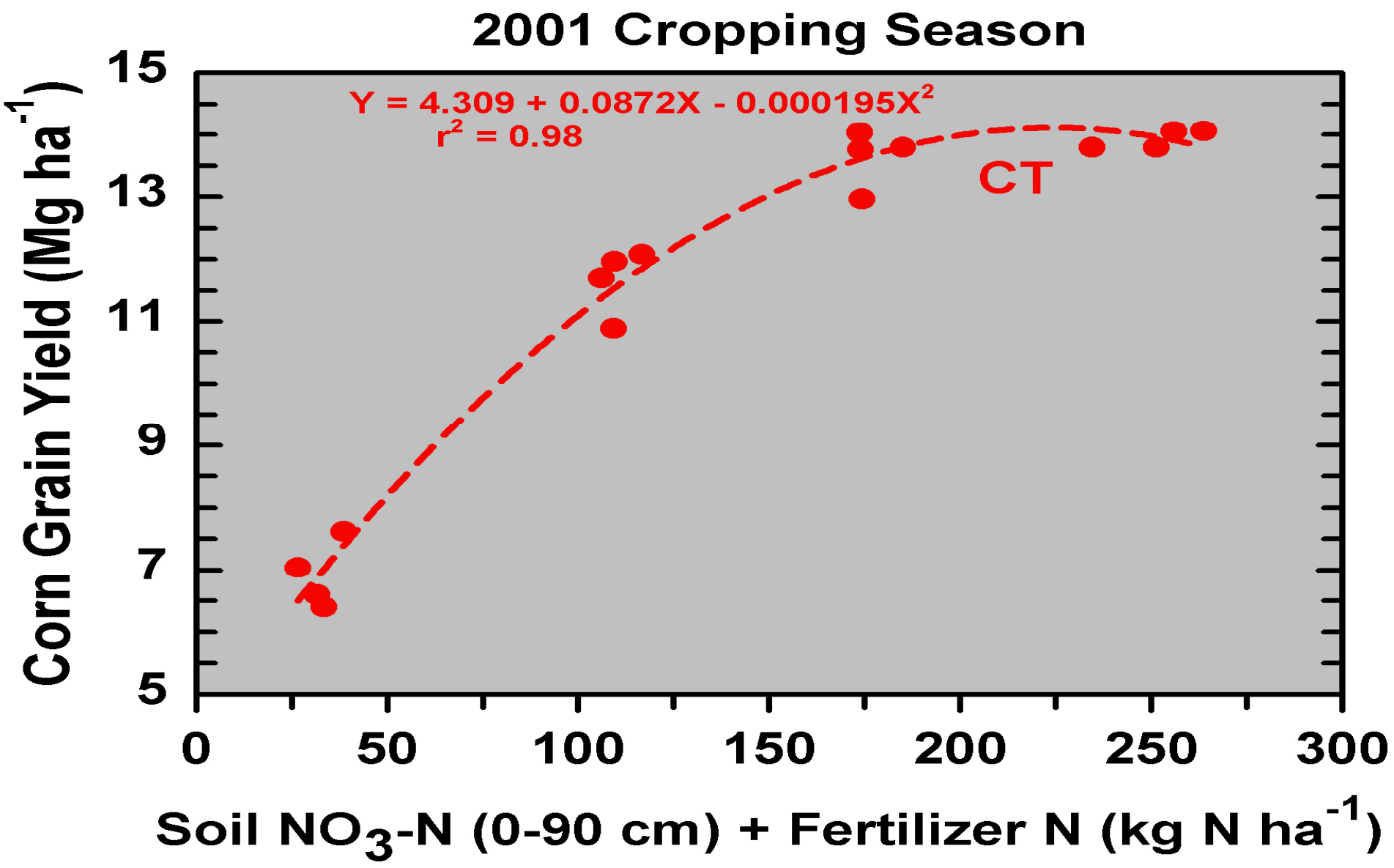
General Concepts Involved in Minimizing N_2O Emissions from Crop Production

Decrease N Requirement for Crop Production by Improving N Use

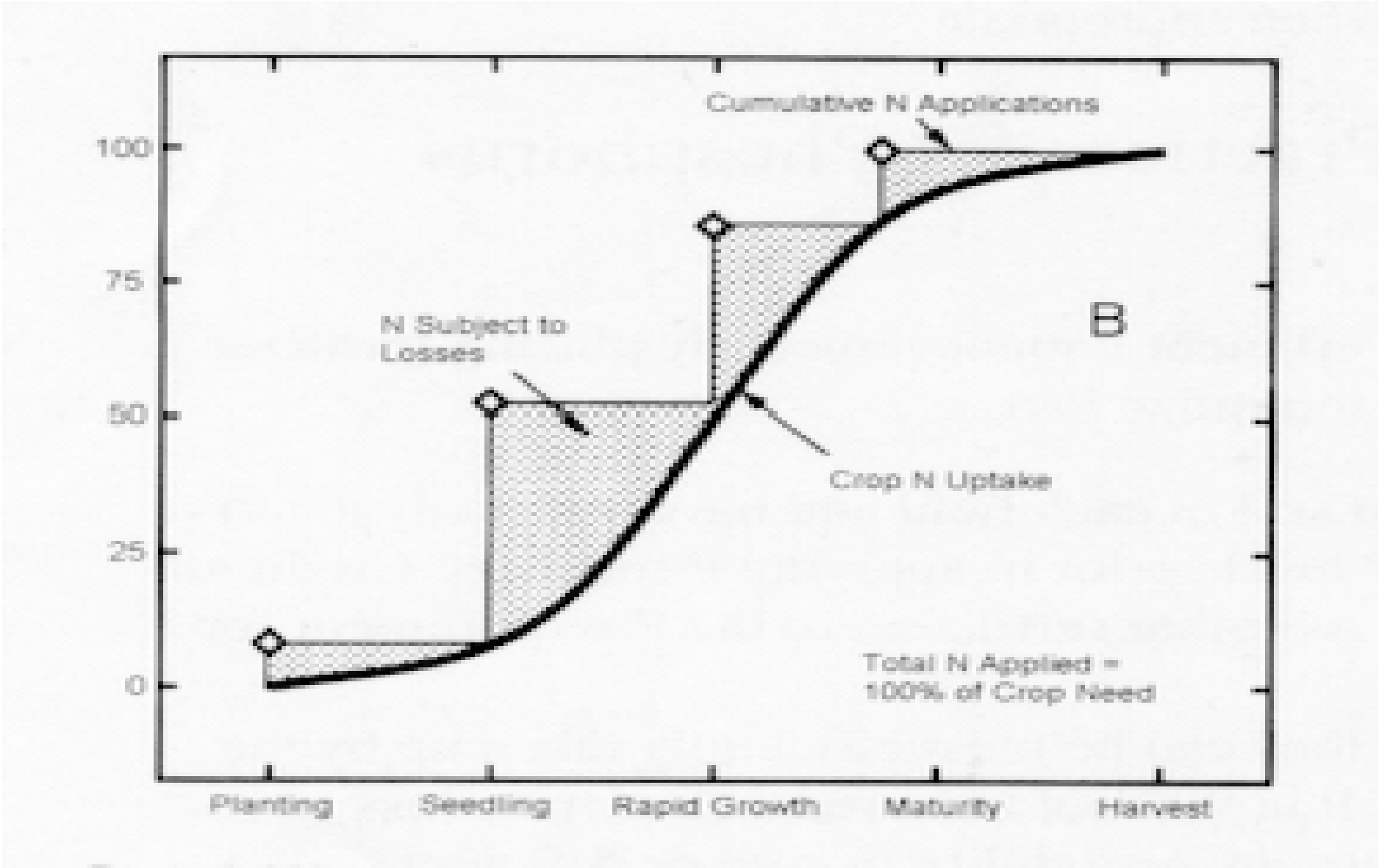
Match N supply with crop demand

- **Tighten N flow cycles**
- **Use advanced fertilization techniques (e.g. control release, inhibitors)**
- **Optimize tillage, irrigation and drainage**

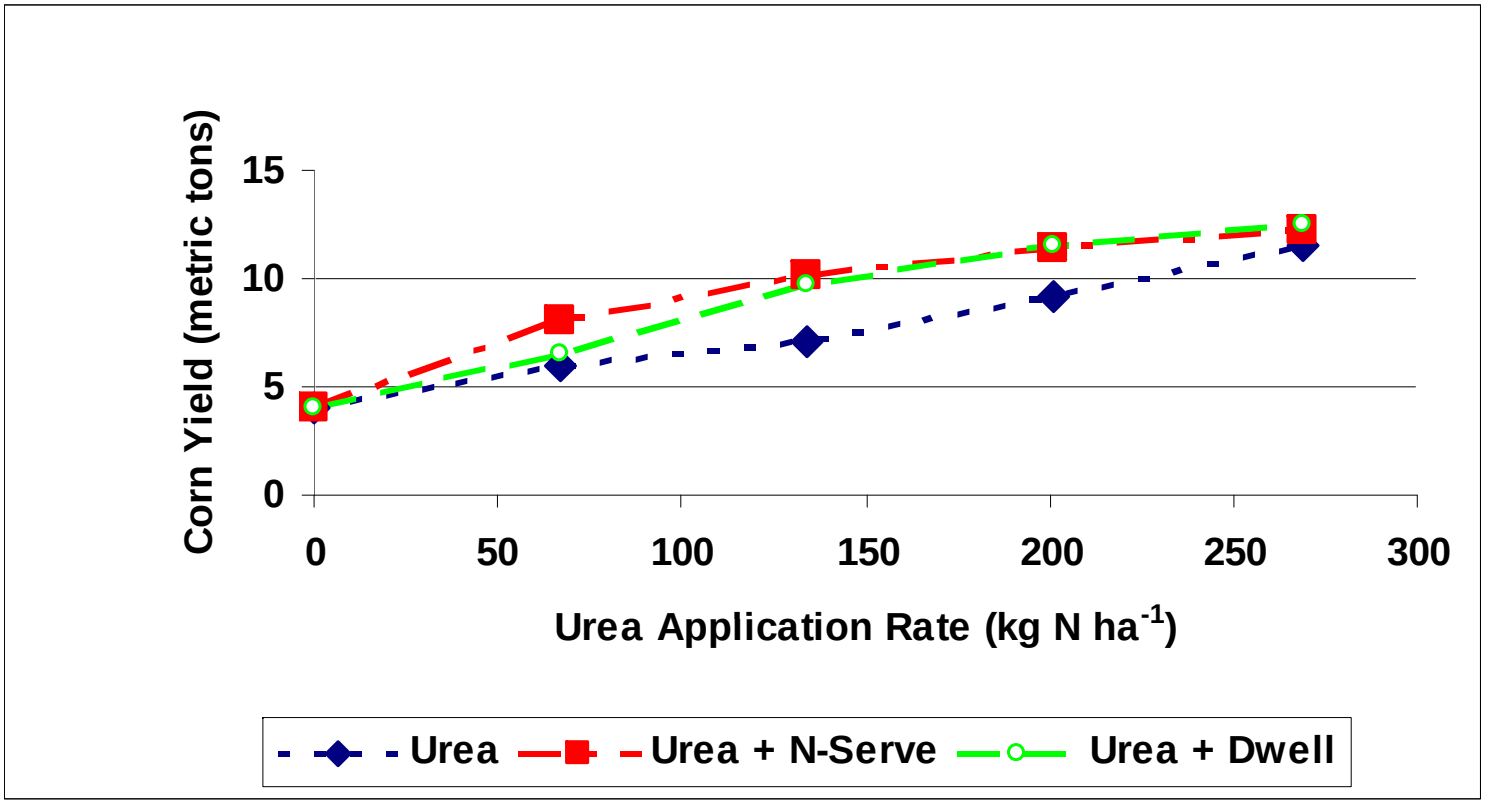
Rate: Match N Supply with Crop Demand



Timing: **Add N to meet timing of crop demand: Multiple additions or control release fertilizers**

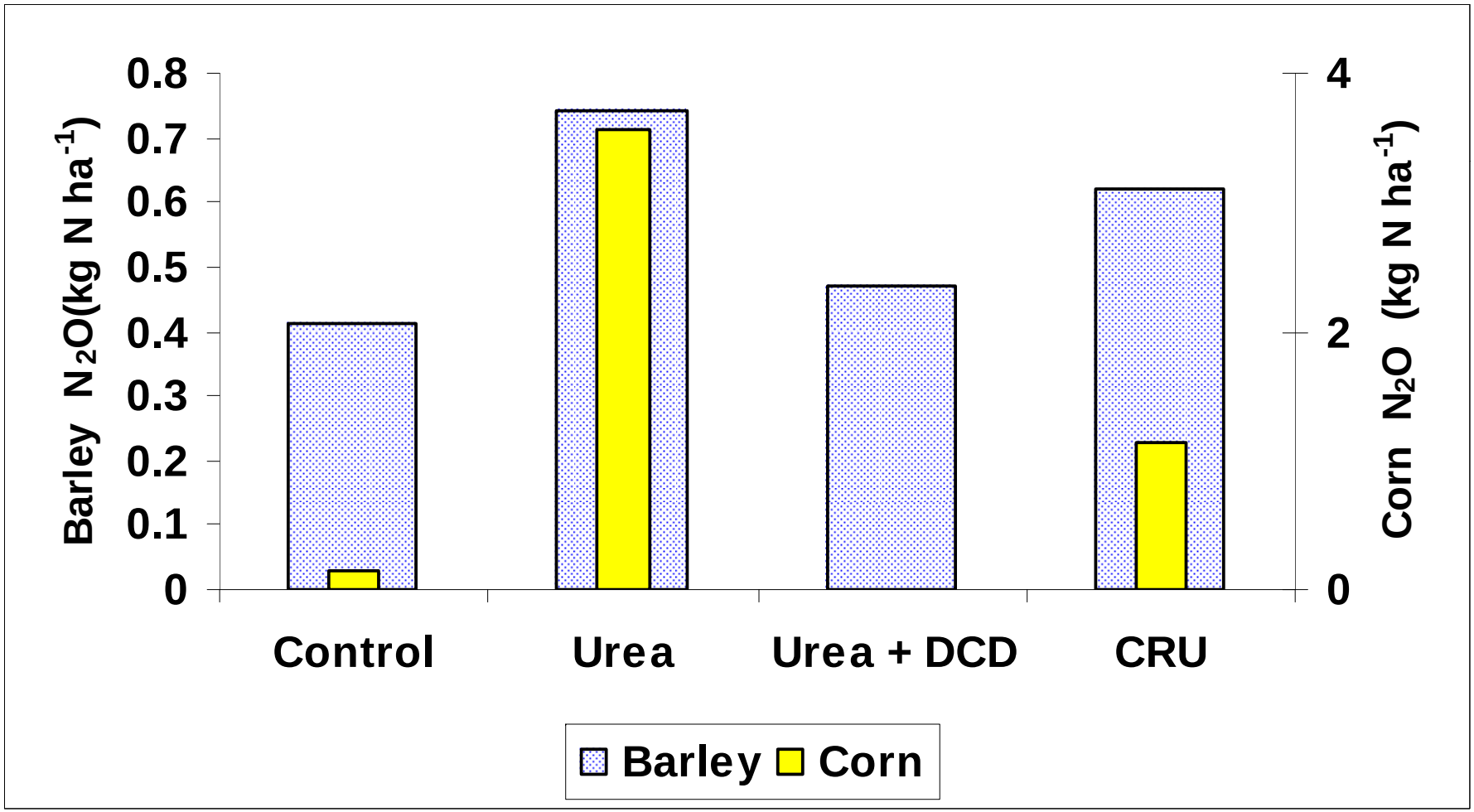


Effect of Nitrification Inhibitors on Corn Yield



National Corn Handbook-NCH-55, 2001

Effect of Control Release Urea & a Nitrification Inhibitor on Growing Season N_2O Emissions in Barley & Corn



A very rough estimate of N application that exceeds the ERS "Criteria Rate"

10-20% of total synthetic N fertilizer and livestock manure

For 2006 N application totaled ~ 14.4 million tons

Note that probably less than half of the potentially available livestock N is not used to fertilizer crops

Estimated total N excess is: 1.4 to 2.8 million tons of N

Corn production is an obvious target for improving N use Efficiency. But where is the remaining ~5 million tons of N used?

How much N_2O is actually generated with each unit of newly created reactive N (N_r)?

- From a historical perspective (top down approach) of accumulation of N_2O in the atmosphere, 3 to 5 % of all newly created N_r is released to the atmosphere as N_2O. This number includes all recycling pathways, and fresh water and coastal zone N_2O emissions. See Crutzen et al., 2008 & Smith et al. 2010.

- IPCC 2006 guidelines break down emissions into direct (1% of all N added)—which includes crop residue N, manure and synthetic fertilizer), and indirect (0.75% of N volatilized or leached from the field). Separate emission factors are given for N_2O produced via livestock N_2O.

- Process modelling typically addresses only in-field production and must rely upon The IPCC defaults to estimate indirect N_2O emissions.

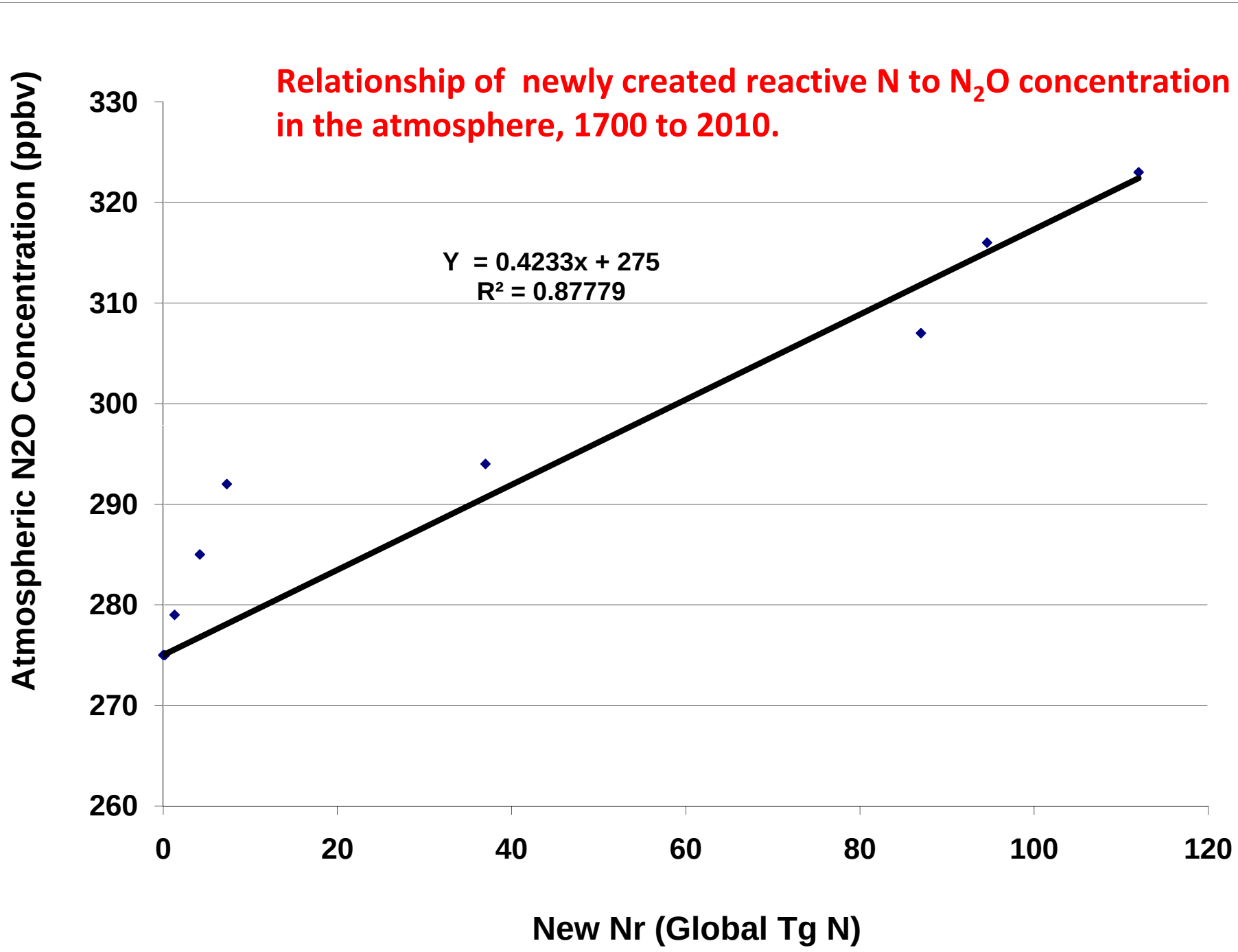
A very rough estimate of potential decrease in USA N_2O emissions that could result from limiting over application of synthetic fertilizer and livestock N

Potential excess N application: 1.4-2.8 million tons of N

Possible N_2O release from this N:

2-5% of this N---0.03 to 0.14 million tons of N_2O-N each year

This equates to 13.6 to 68 million tons of CO_2 equivalents per year


Relationship of newly created reactive N to N_2O concentration in the atmosphere, 1700 to 2010.
Y = 0.4233x + 275
R² = 0.87779
Atmospheric N2O Concentration (ppbv)
330
320
310
300
290
280
270
260
0
20
40
60
80
100
120
New Nr (Global Tg N)