Food Security, Fertilizer and the Environment : A Wicked Troika

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This Troika as a Wicked Problem

Tame vs. Wicked

The Problem

Tame Problem

- The clear definition of the problem also unveils the solution
- The outcome is true or false. Successful or unsuccessful
- The problem does not change over time.

Wicked Problem

- No agreement about what the problem is. Each attempt to create a solution changes the problem.
- The solution is not true or false – the end is assessed as "better" or "worse" or "good enough."
- Problem changes over time.

The Role of Stakeholders

Tame Problem

- The causes of a problem are determined primarily by experts using scientific data.

Wicked Problem

- Many stakeholders are likely to have differing ideas about what the "real" problem is and what are its causes.

Nature of the Problem

Tame Problem

- Scientifically based protocols guide the choice of solution(s).
- The problem is associated with low uncertainty as to system components and outcomes.
- There are shared values as to the desirability of the outcomes.

Wicked Problem

- Solution(s) to problem is (are) based on "judgments" of multiple stakeholders.
- The problem is associated with high uncertainty as to system components and outcomes.
- There are not shared values with respect to societal goals.

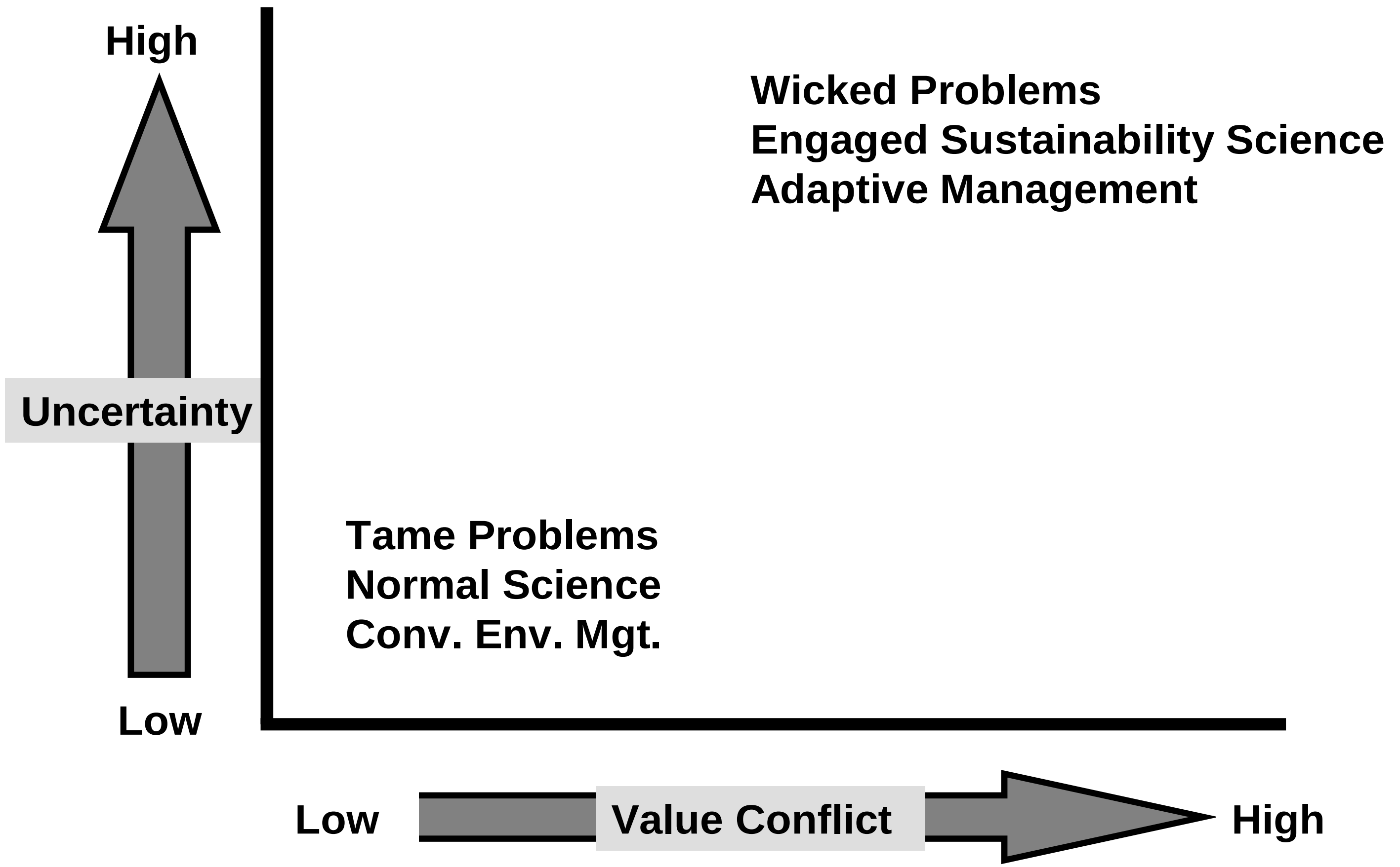
The “Stopping Rule”

Tame Problem

- The task is completed when the problem is solved.

Wicked Problem

- The end is accompanied by stakeholders, political forces, and resource availability. There is no definitive solution.

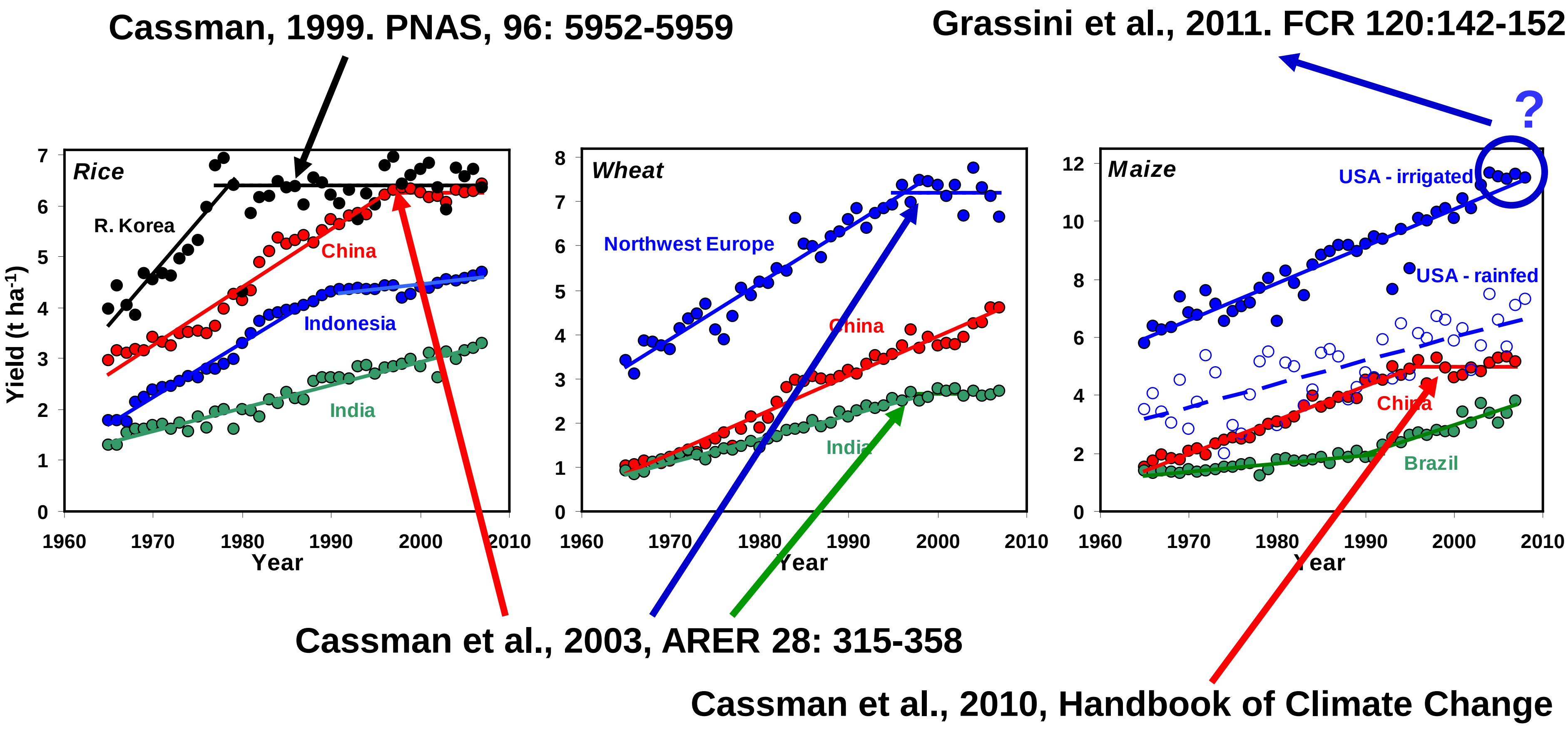


Tame vs. Wicked

Some key food production challenges

- *Water*
- *Yield Plateaus*
- *Intensification*

Korea and Yield plateaus are evident for several cereal crops in some major producing countries: *China for rice, wheat in northwest Europe and India, maize in China and…….perhaps also for irrigated maize in the USA.*



Bottom Line on Yield Trends

- Cereal crop area limited by increasing urbanization due to population growth and economic development, scarcity of unfarmed areas with soil quality suitable for supporting intensified systems, and concerns about loss of wildlife habitat and biodiversity
- Current rates of gain in crop yields not adequate to meet expected demand for food, feed, fiber, and fuel on existing crop land
- Little scope for increasing irrigated crop area due to competition for water with other sectors
- Little increase in yield potential of maize or rice for the last 30-40 years; yield stagnation in some areas
- Is there scope for a quantum leap in yields from biotechnology?

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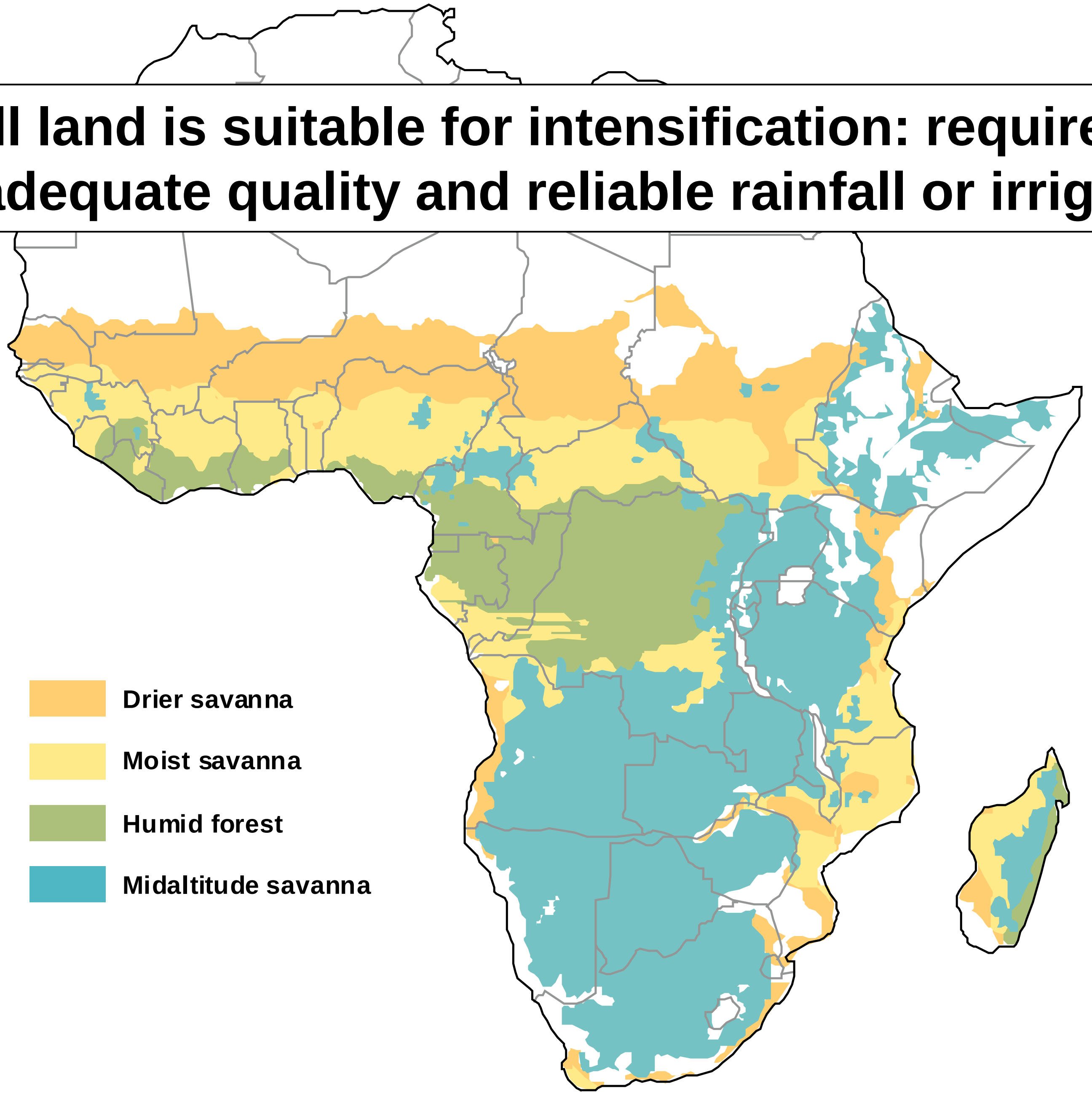
- **Little scope for quantum leap in yields from biotechnology**
- **Need for ecological (sustainable) intensification**

Sustainable Intensification

How high can average farm yields go using crop and soil management practices that conserve natural resources, protect environmental quality, and give an acceptable rate of economic return?

Not all land is suitable for intensification: requires soils of adequate quality and reliable rainfall or irrigation



Ecological Intensification

- **Achieving high-yield crop production systems that protect soil and environmental quality and conserve natural resources**
- **Characteristics of EI systems:**
  - **Yields that are 80-85% of genetic yield potential**
  - **Uses best adapted crop germplasm**
  - **70-80% N fertilizer uptake efficiency (vs 30-50% now)**
  - **Improves soil quality (nutrient stocks, SOM)**
  - **Uses integrated pest management (IPM)**
  - **Achieves a net reduction in GHG emissions**
  - **Has a large net positive energy balance**
  - **In irrigated systems: 90-95% water use efficiency**

¶Cassman, 1999. *in* Proc. Natl. Acad. Sci (USA):5952-5959

Ecological intensification is knowledge-intensive and requires:

- New knowledge derived from field research focused on improving productivity, soil quality, and environmental services simultaneously

- An integrated systems approach

- Decision-support tools for responsive, real-time, in-season crop and soil management (precision agriculture)

  - *Need for good quality soil and long-term weather databases (daily temp, rainfall, solar radiation)*
  - *Could farmers in developing countries have a comparative advantage due to scale of farming?*

The Dilemma of Nitrogen:

Too Much of a Good Thing

Nitrogen Drivers in 1860 and Now

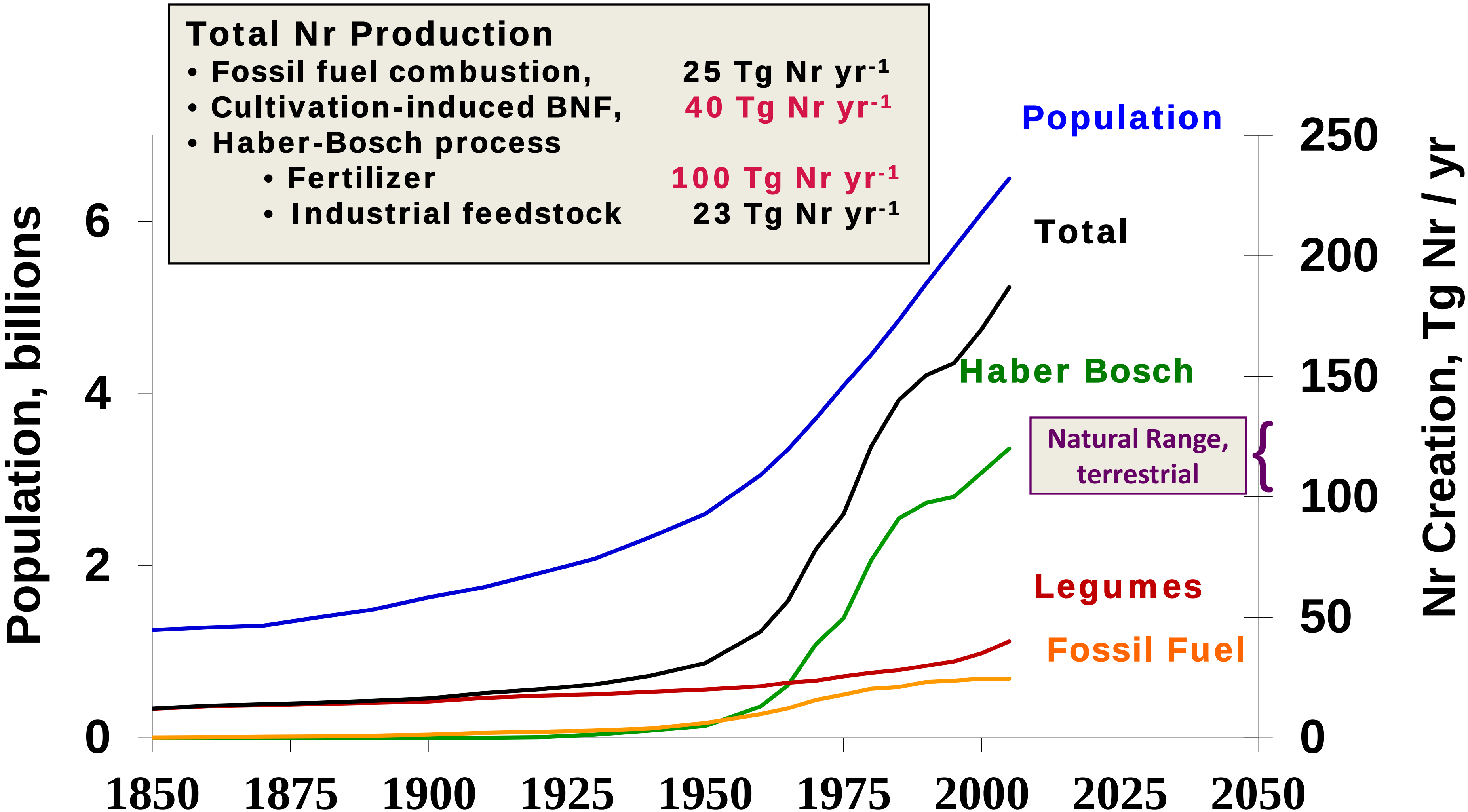
Grain Production

Meat Production

Energy Production

Global Nr Creation by Human Activity 1850 to 2005

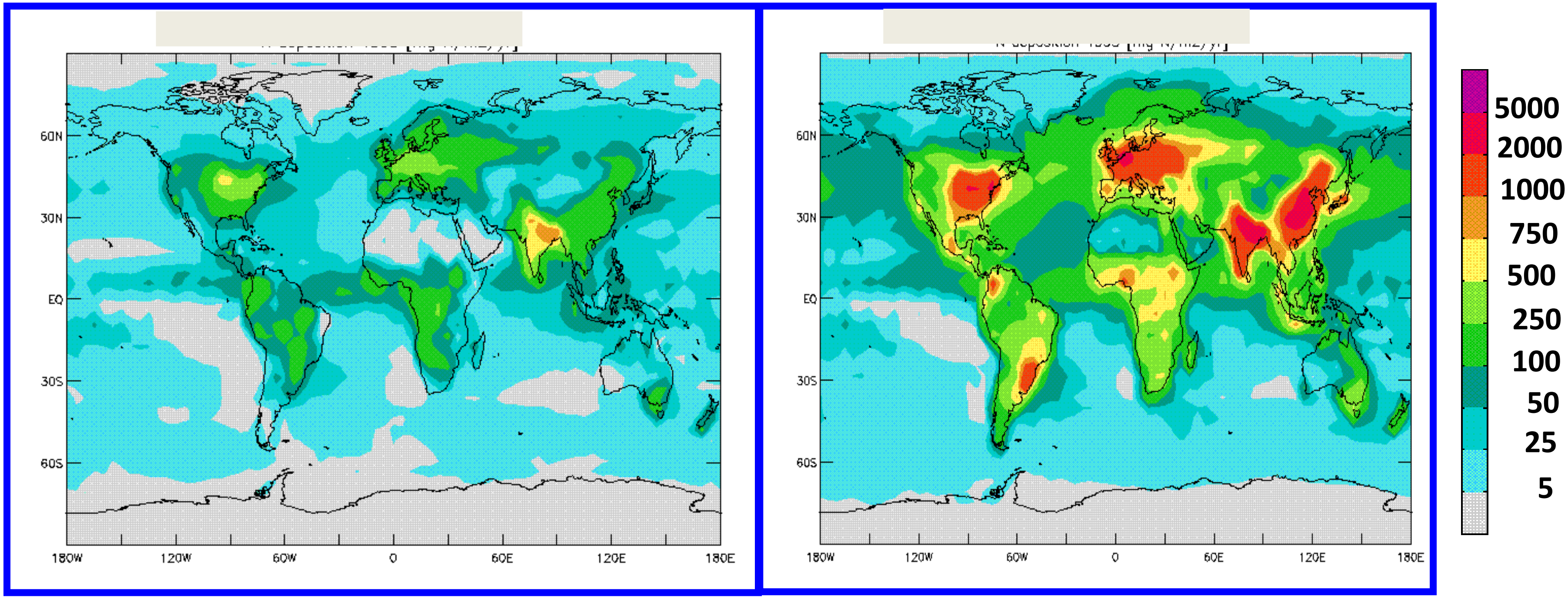
In 2005 ~190 Tg Nr was created by humans.



Galloway et al., 2003

Nitrogen Deposition

mg Nr/m^2/yr

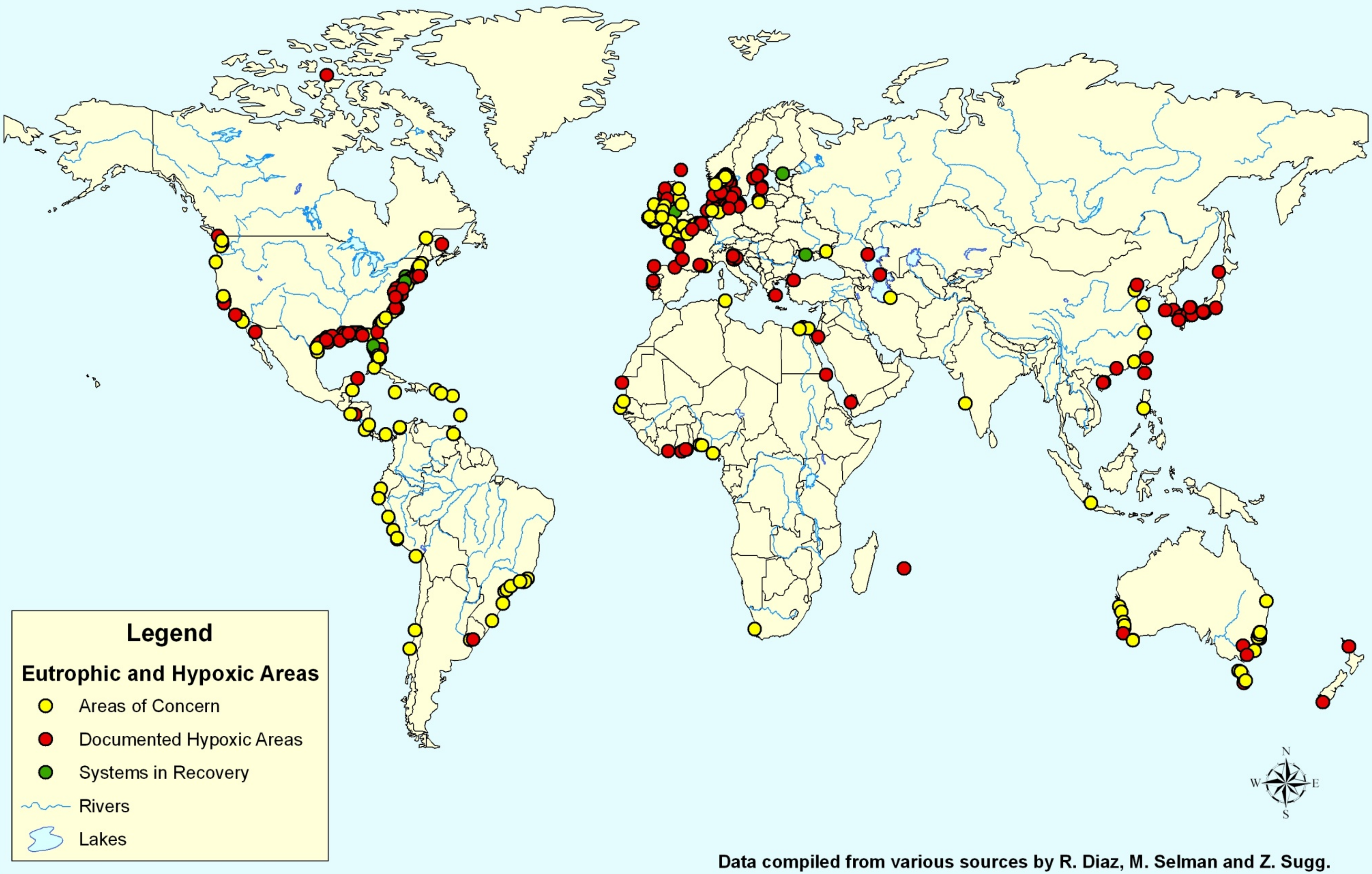


1860 **2000**

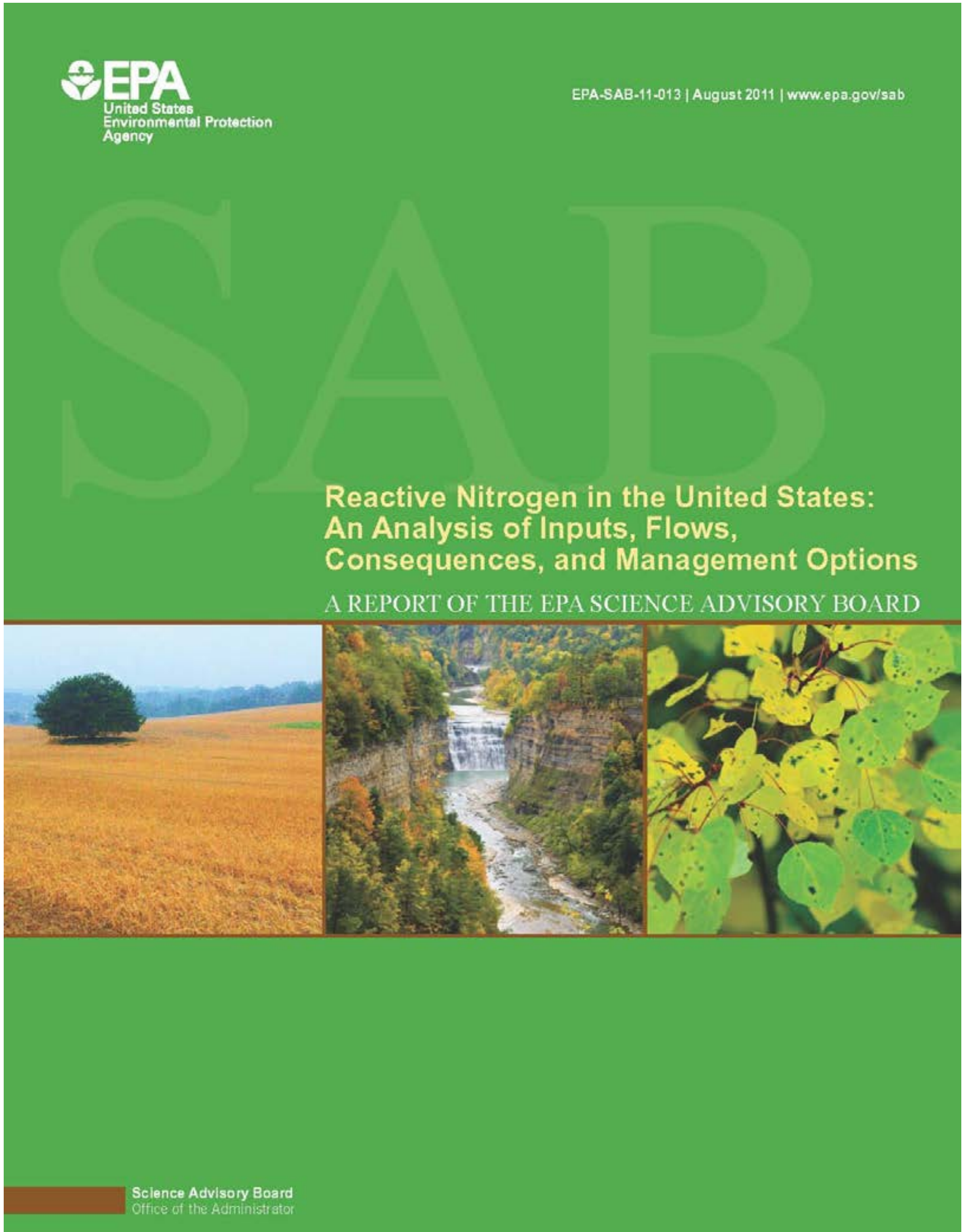
- Nitrogen emitted as NOx to atmosphere by fossil fuel combustion
- Nitrogen emitted as NH_3 and NOx from food production
- Once emitted, it is transported and deposited to ecosystems
- In 1860, human activities had limited influence on Nr deposition
- By 2000, the picture had changed

Galloway et al., 2004

World Hypoxic and Eutrophic Coastal Areas



Data compiled from various sources by R. Diaz, M. Selman and Z. Sugg.

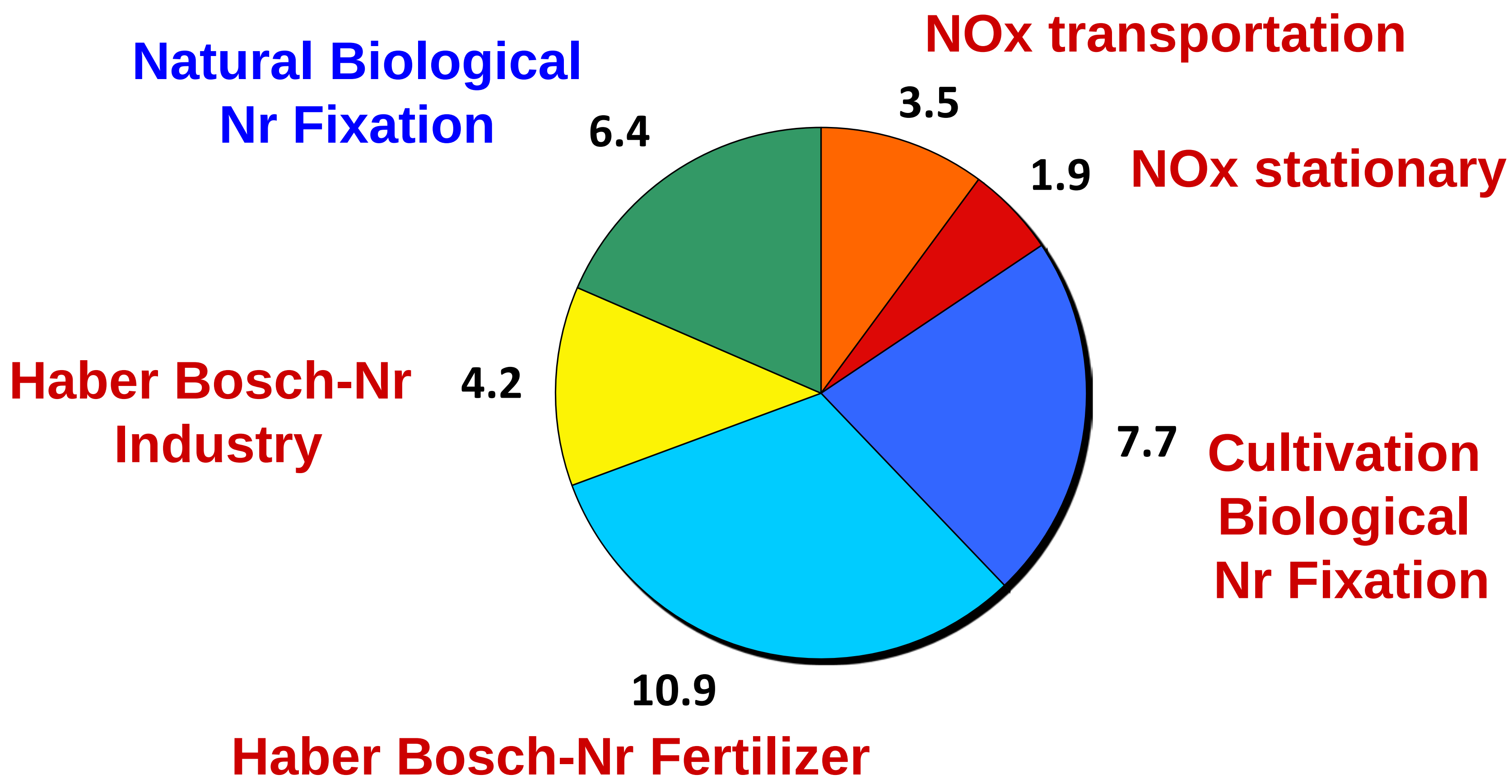


Reactive Nitrogen in the United States:
An Analysis of Inputs, Flows, Consequences and Management Options

-- EPA Science Advisory Board's Integrated Nitrogen Committee final report

Nr Introduction into the US

Tg Nr/yr



Natural, 6.4 Tg Nr/yr

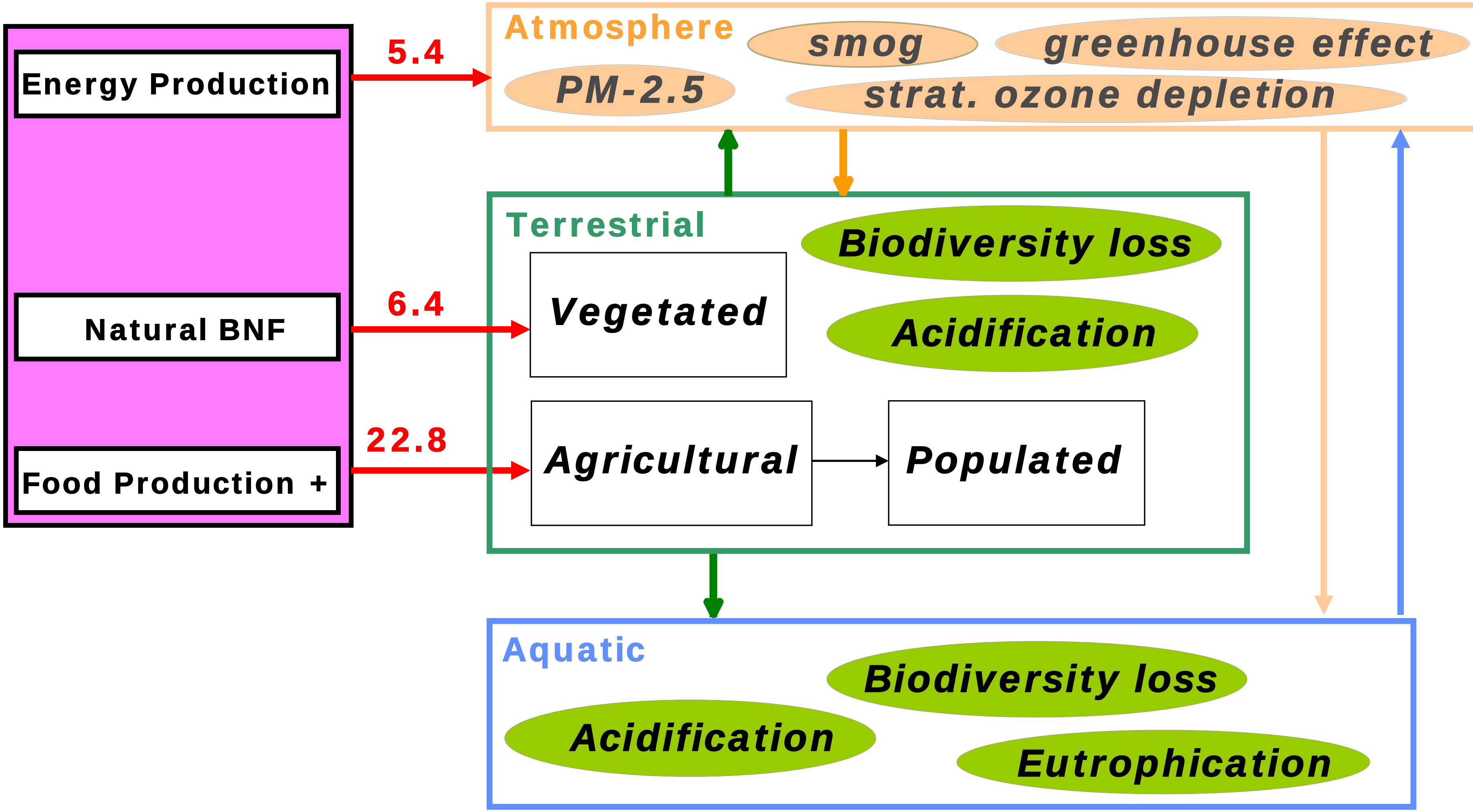
Anthropogenic, 29 Tg Nr/yr

Identification of Control Points to Management Reactive N in the US

- The overarching objective is to maintain the benefits of nitrogen while minimizing the losses to the environment

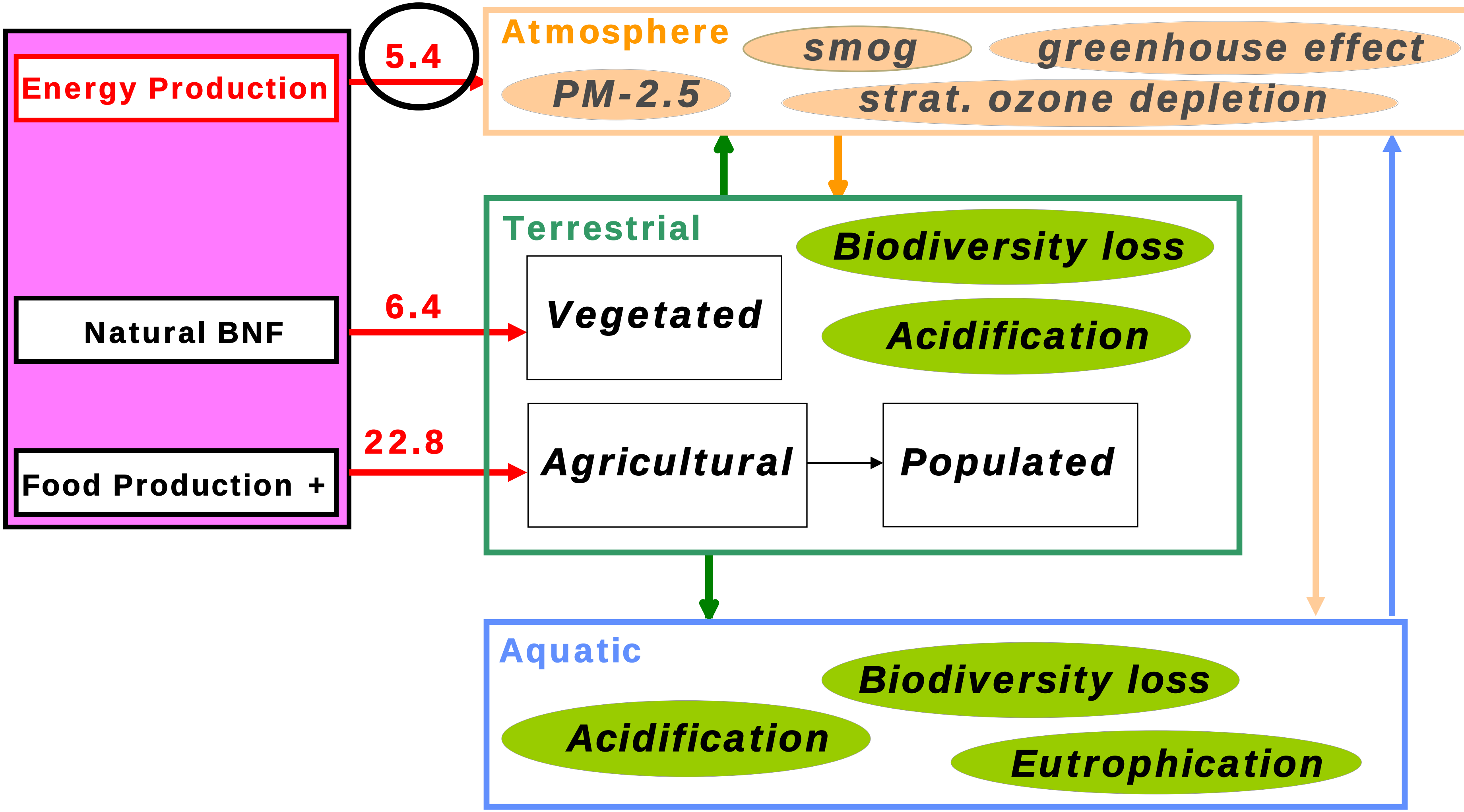
- For control points of Nr in the cascade we set the following priorities:
    - Where is Nr creation not needed?
    - Where can Nr use be made more efficient?
    - Where can Nr wastes be managed?

Management of Nitrogen: Three Priorities



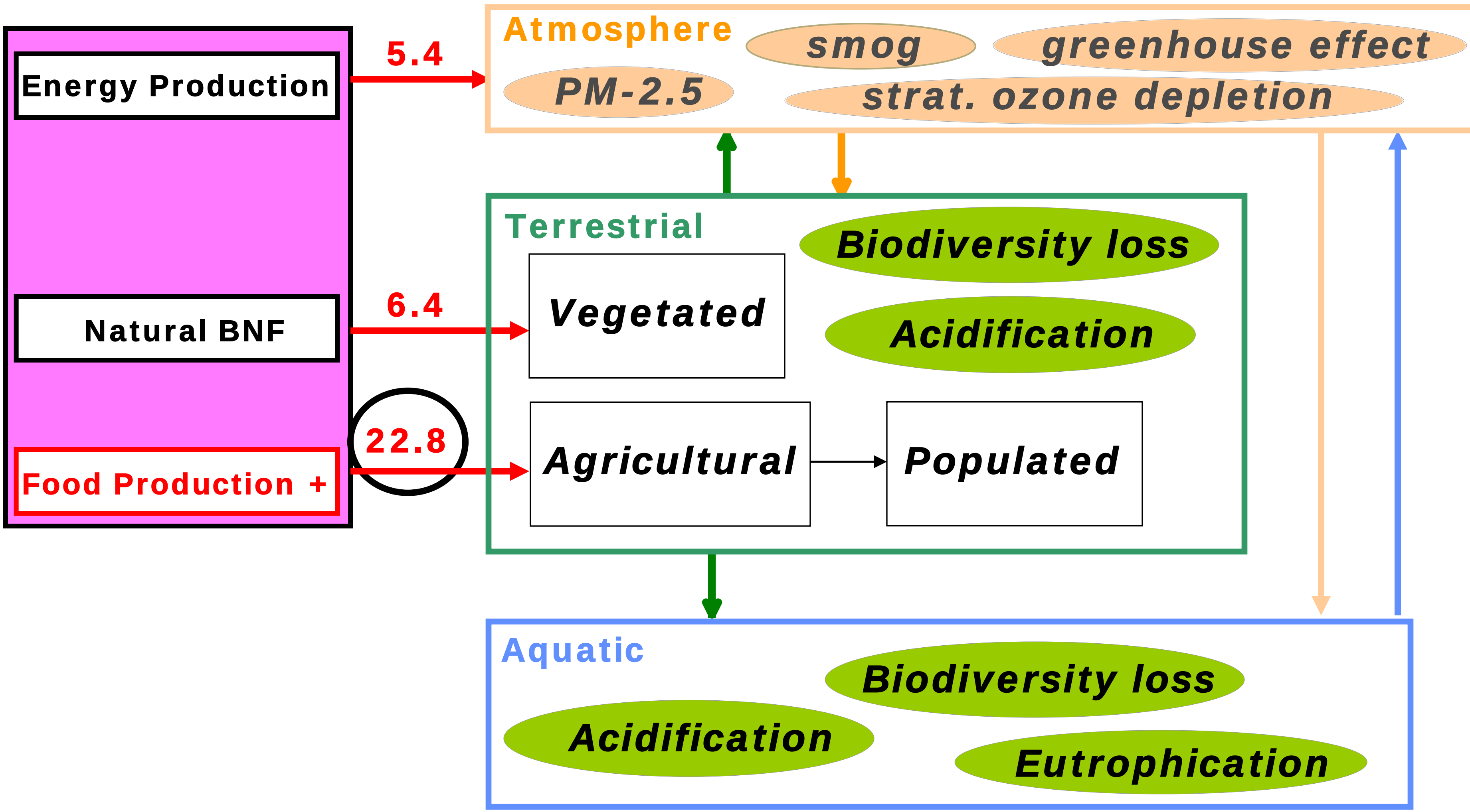
As shown above, ~35 Tg Nr / yr are introduced in the USA by natural processes, food production and energy production.
Once introduced, it has beneficial and detrimental impacts on ecosystems and humans.

First Priority: Nr not Needed



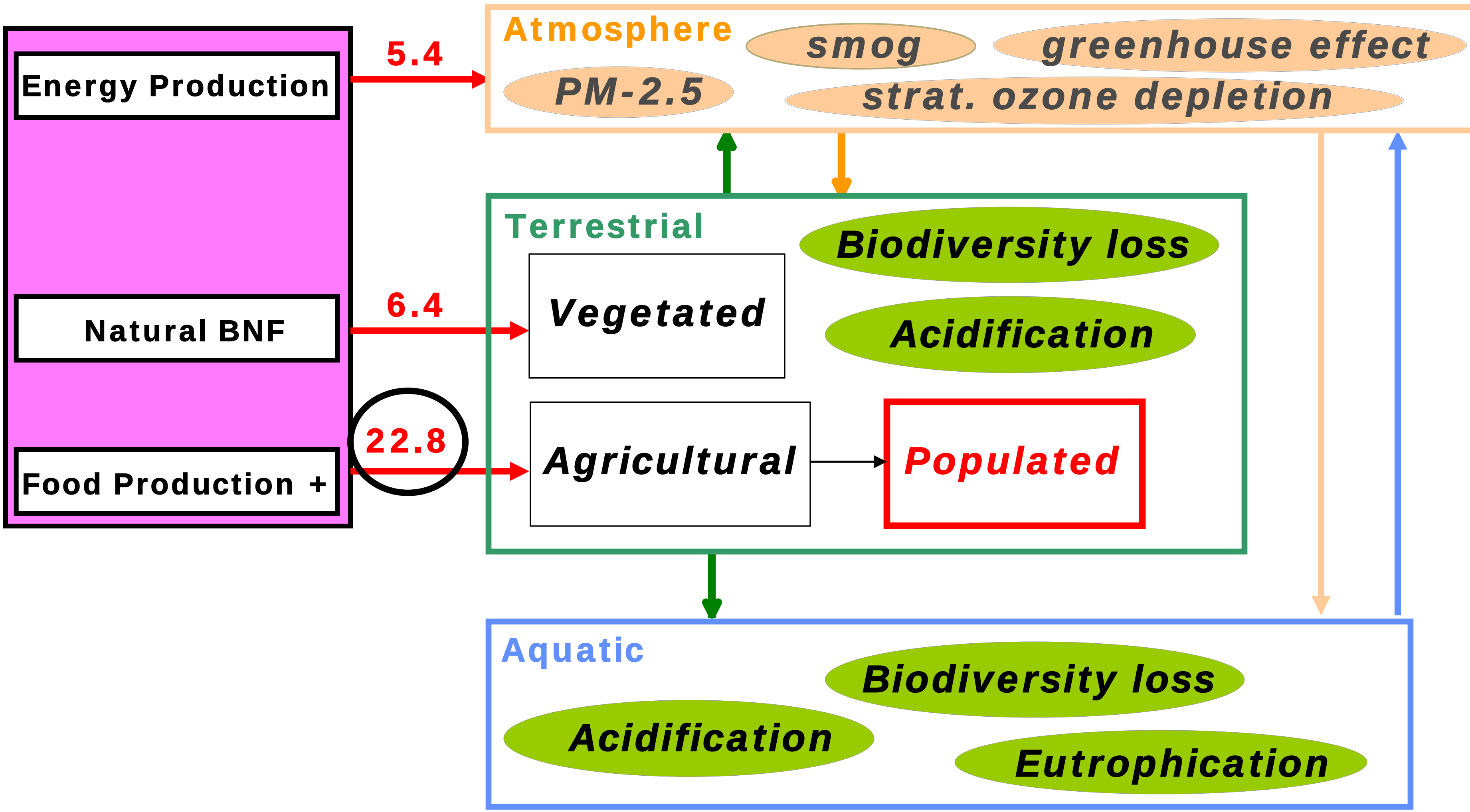
By using existing technology, EPA can expand its NOx control efforts to include 90% decreases of emissions from heavy-duty on-road, all off-road mobile sources and currently uncontrolled electricity generation and industrial processes. This would decrease Nr formation by **2 Tg Nr/yr**.

Second Priority: Increase Nr Use Efficiency



By using currently available technology crop and animal N-uptake efficiencies can be increased through a combination of knowledge-based practices and advances in fertilizer and feeding technologies. This would decrease the amount of Nr applications to crop lands by **~3 Tg Nr/yr**.

Third Priority: Manage Nr Wastes



By improving human waste treatment practices using existing technology we would decrease Nr losses by **0.5 to 0.8 Tg Nr / yr**.

The same technologies could be used for animal waste for a decrease of **0.5 Tg Nr / yr.**

U.S. Trends in Corn Grain Produced per unit Applied Fertilizer N

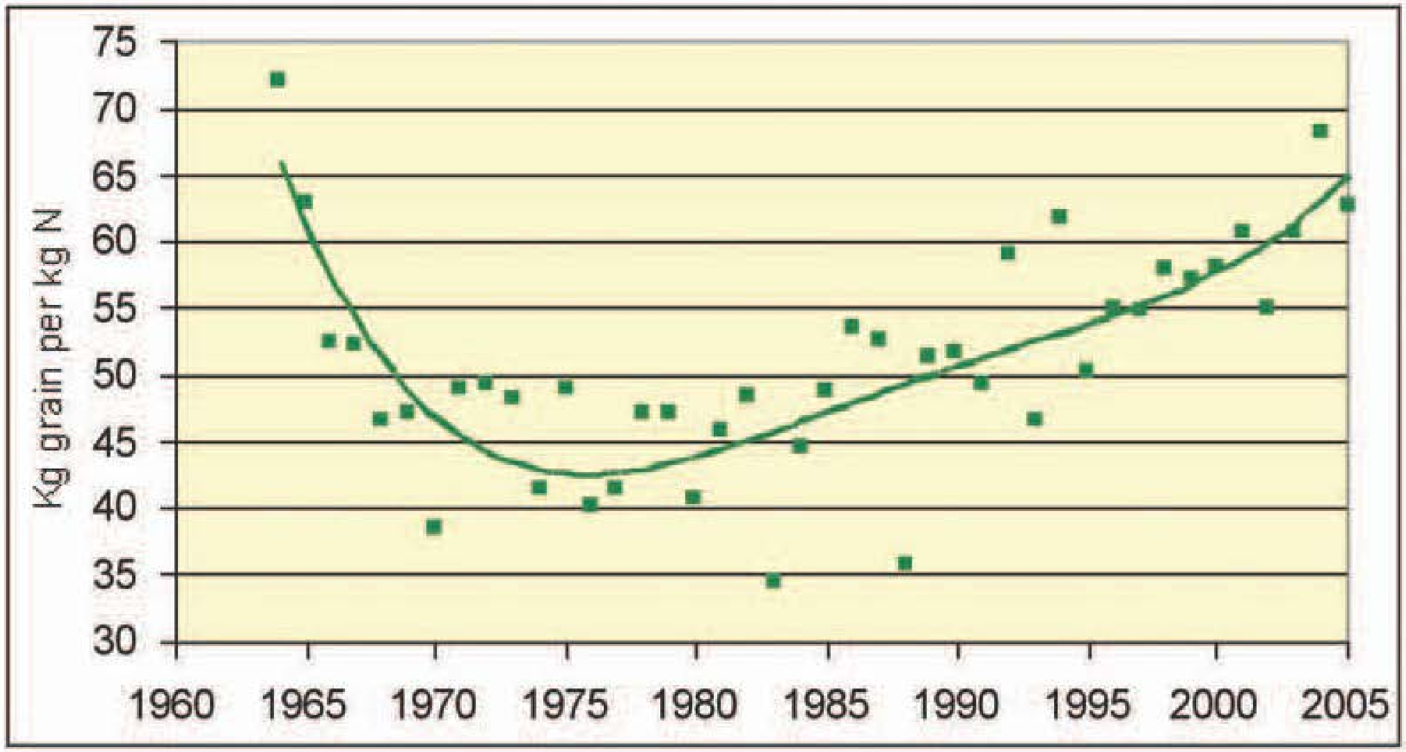


Figure 7: Trends in corn grain produced per unit of applied fertilizer N (NFUE) in the United States

Source: Adapted from Fixen and West, 2002 (Figure 6). Adapted with permission; Copyright 2002, Springer Science+Business Media B.V. on behalf of the Royal Swedish Academy of Sciences.

Take Away Message

For the US, there are several actions that can be taken to decrease both Nr creation, and Nr losses to the environment:

- Fossil fuel combustion
- Fertilizer uptake
- Feed retention
- Manure management
- Sewage treatment

If all were taken, there would be a 25% decrease in Nr loss to the environment.

What are our Food Security, Fertilizer and Environmental Challenges?

- Short Term - Long Term
- Public Sector - Private Sector

Where Do We Start?

- Recognizing the problem - *building consensus*
- Defining the problem in terms of its nature
- Aligning institutions with the integrated job to be done
- Metrics Matter
- Setting Goals for Action

A Start

Our Earth