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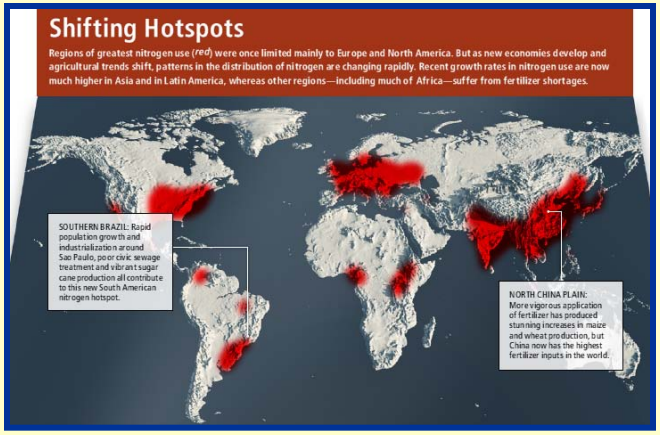
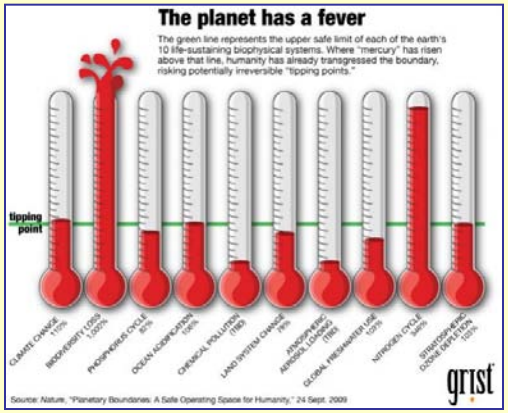



# Nutrient Pollution of Coastal Waters: Trends, Drivers, and Potential Solutions



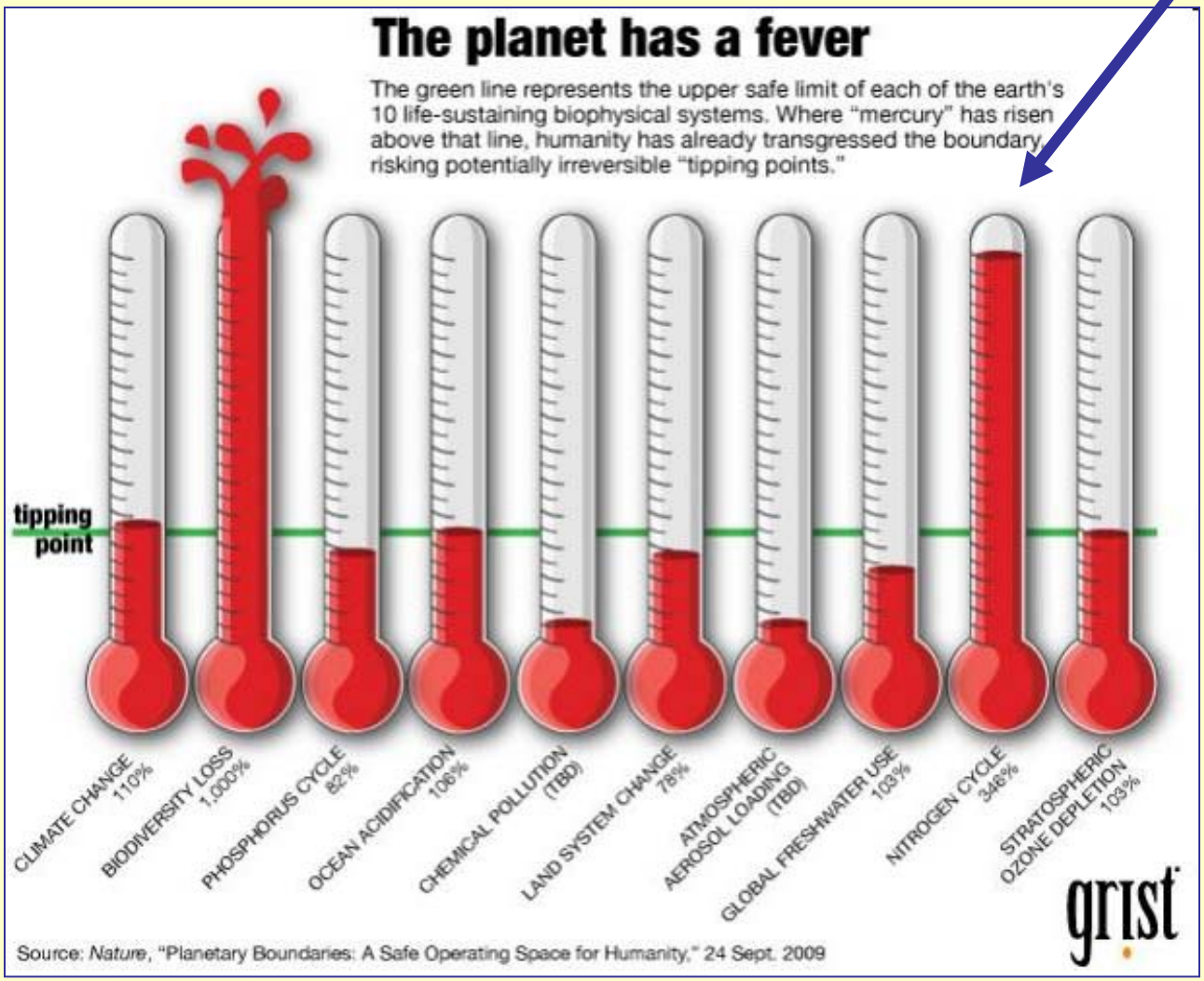

**Robert Howarth**
Cornell University
Ithaca, NY USA

## Ocean Hypoxia and its Impacts on Ecosystems
UNDP Side Event at GESAMP #39
New York City, USA

18 April 2012

# Global status of earth's 10 life-sustaining biophysical systems

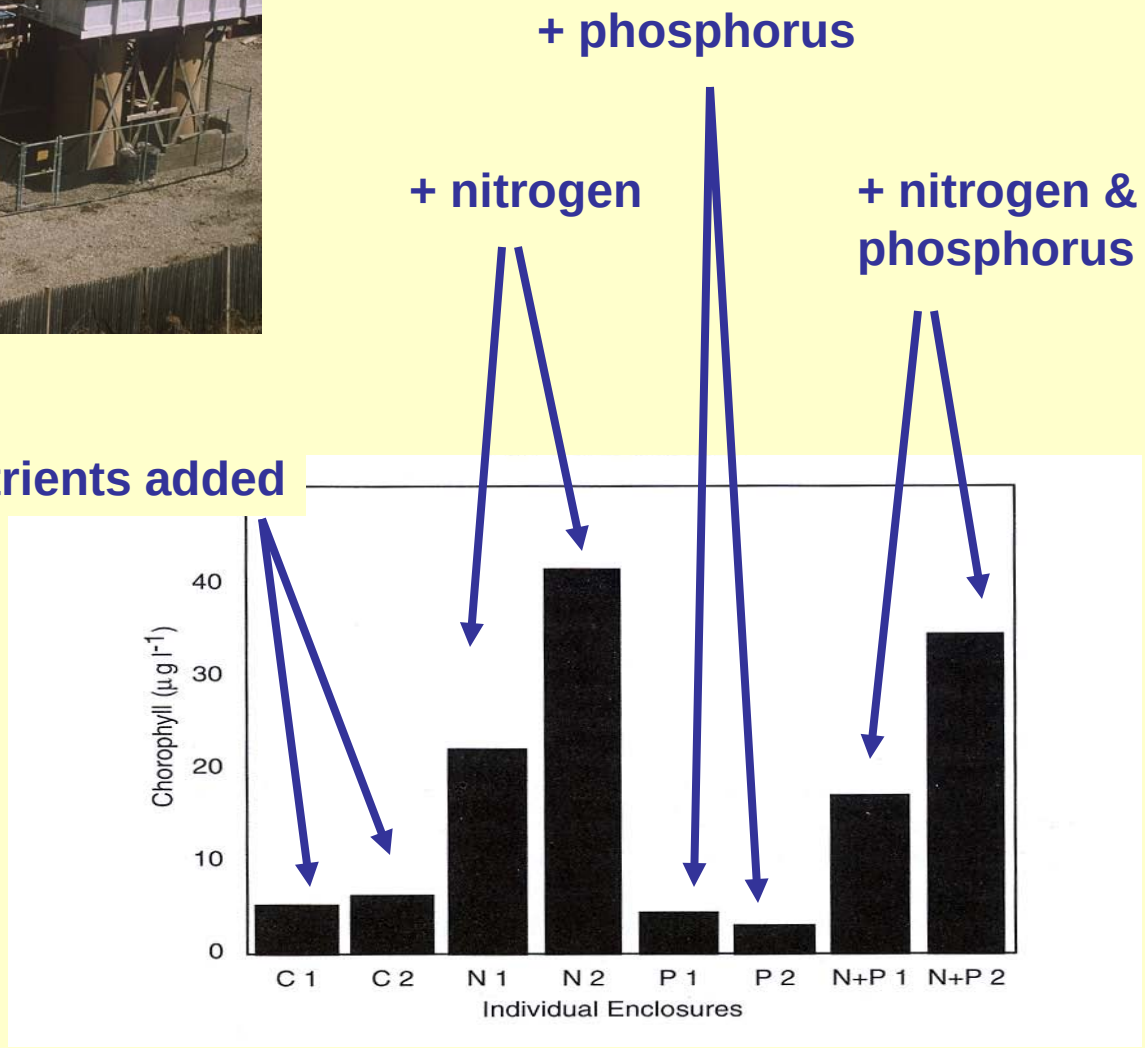
nitrogen




(Rockstrom et al. 2009)

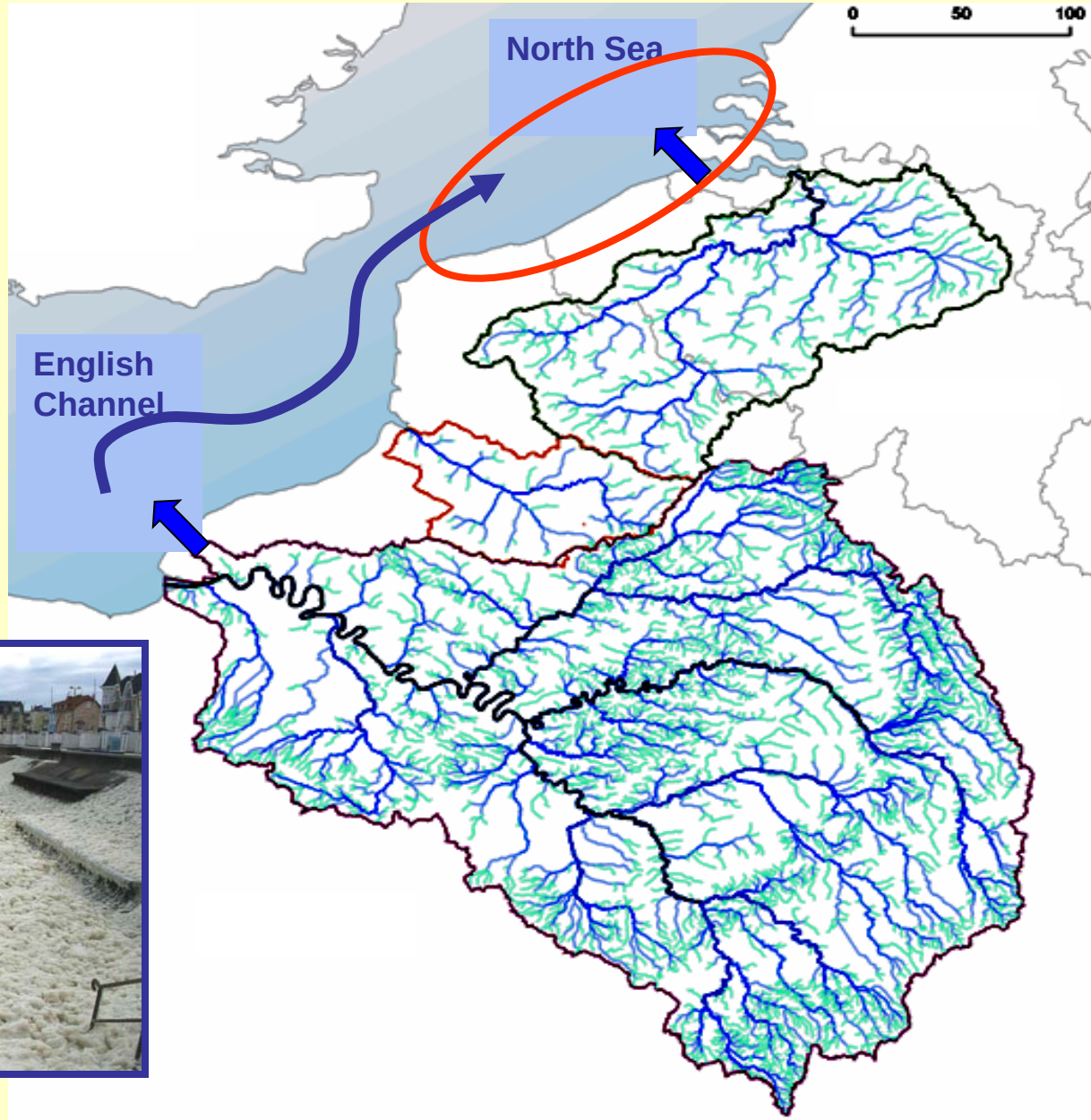
**Nitrogen (and not phosphorus) is the primary culprit for coastal eutrophication and hypoxia**

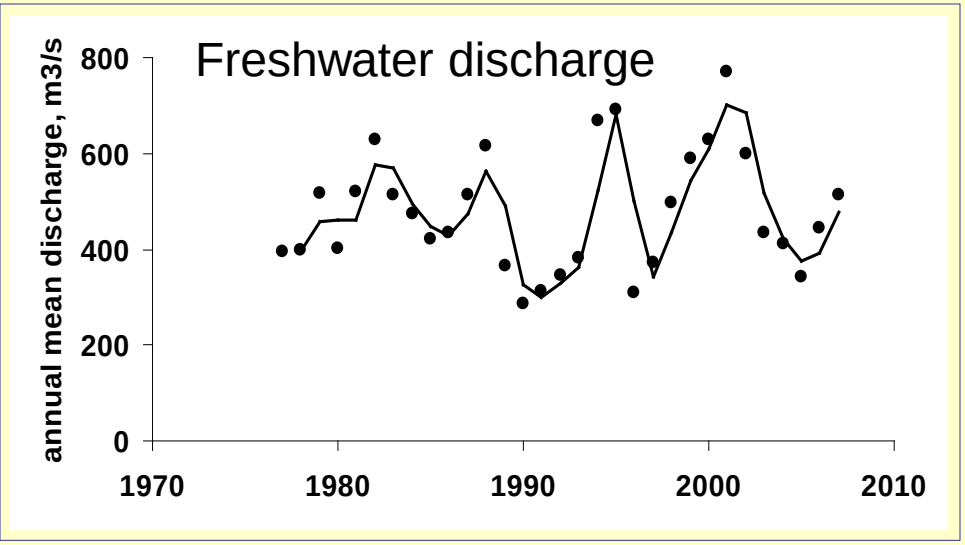
**(although controlling both is best policy)**



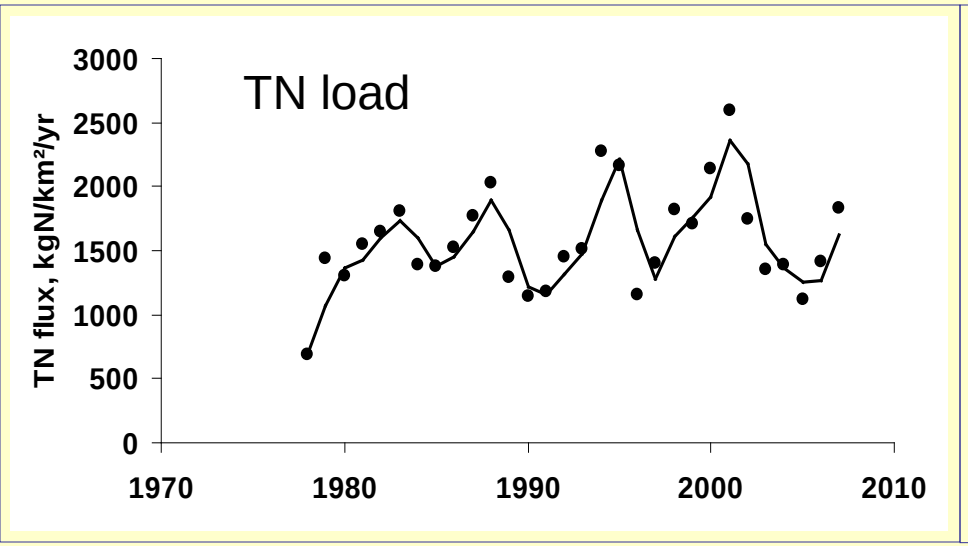

Oviatt et al. 1996

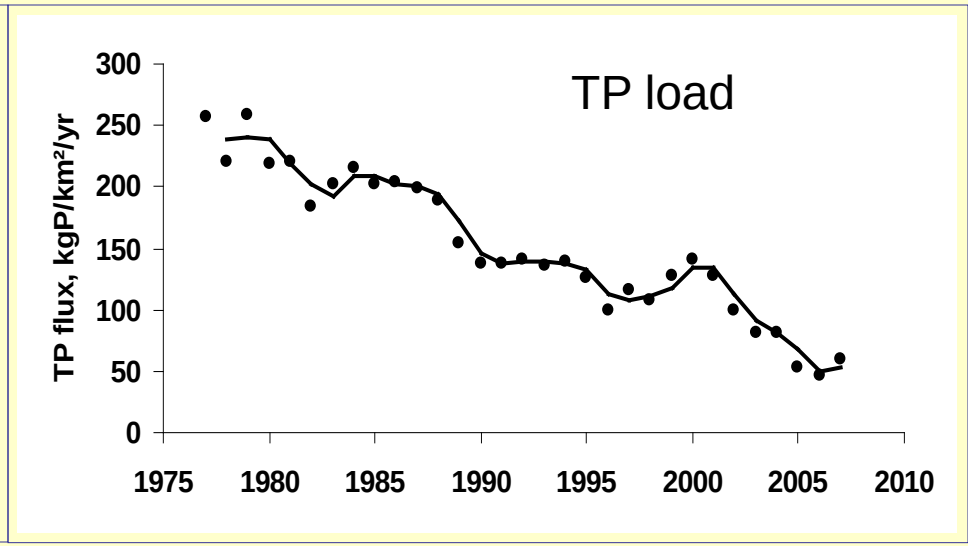
# Seine and Scheldt Basins and Belgian coast of North Sea

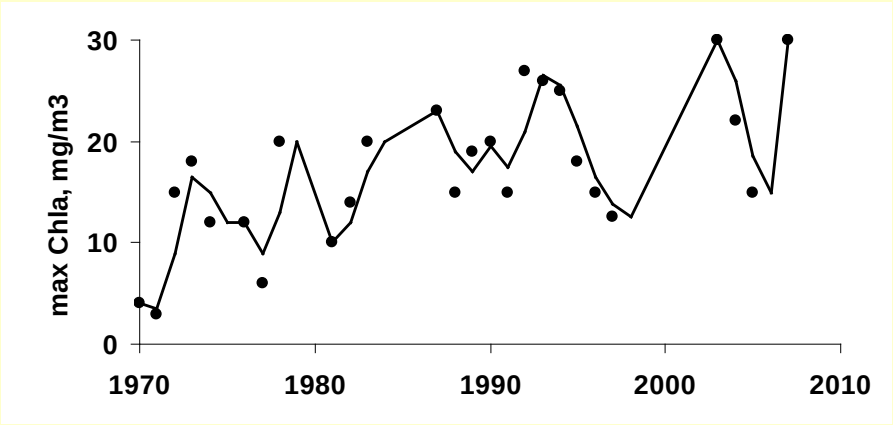


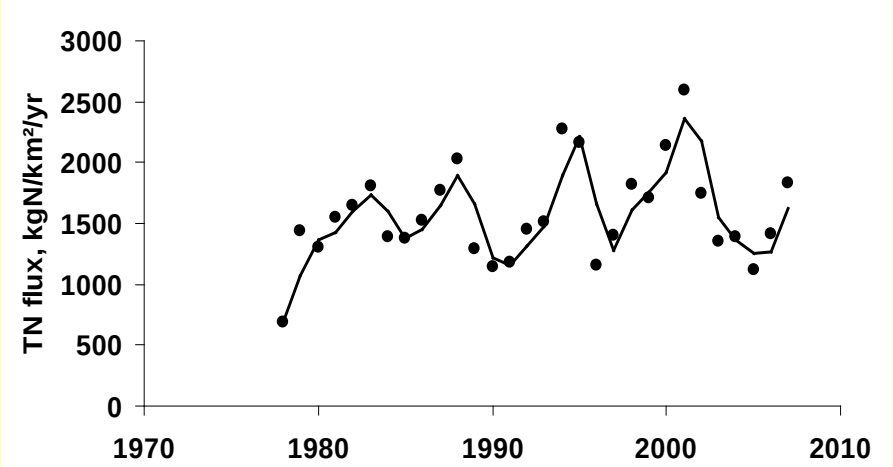

# Seine River basin



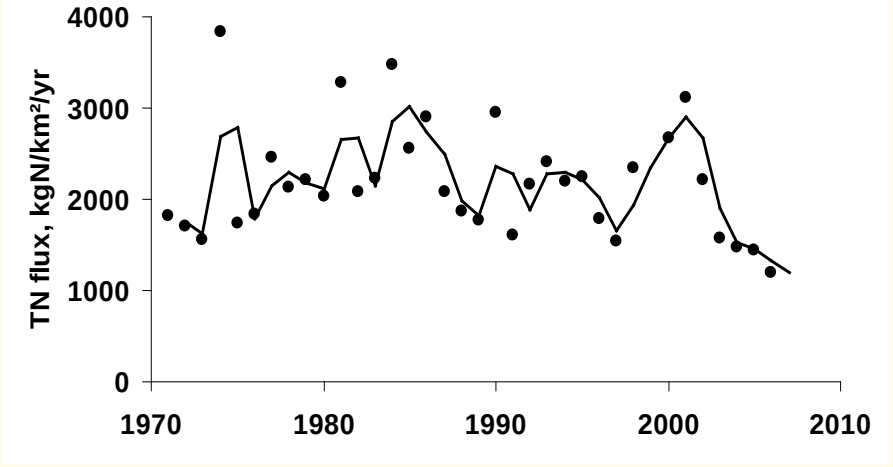






**Chlorophyll in North Sea on Belgian coast**

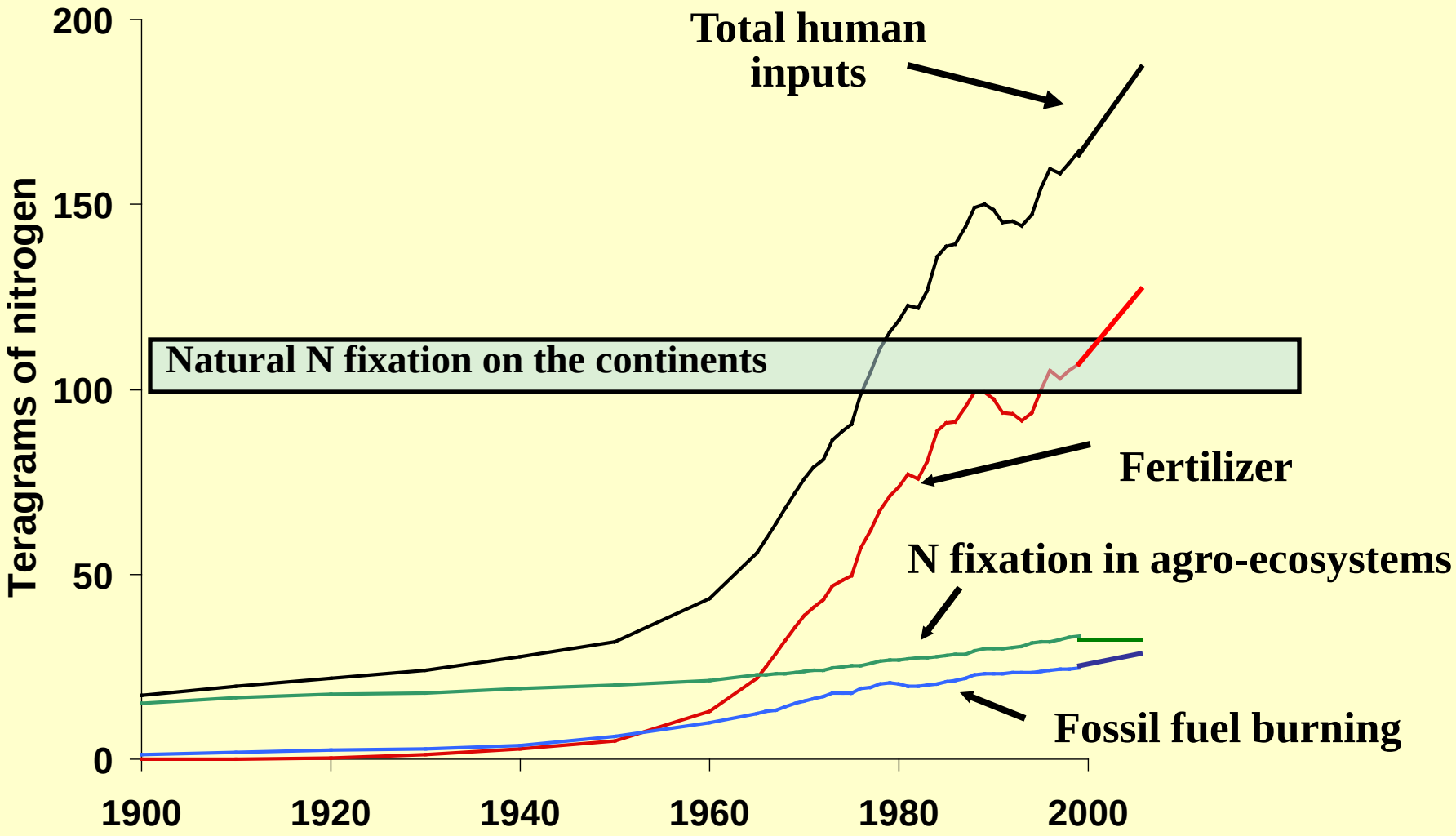



**Seine River N load**




**Scheldt River N load**

# Global trends in nitrogen use per year

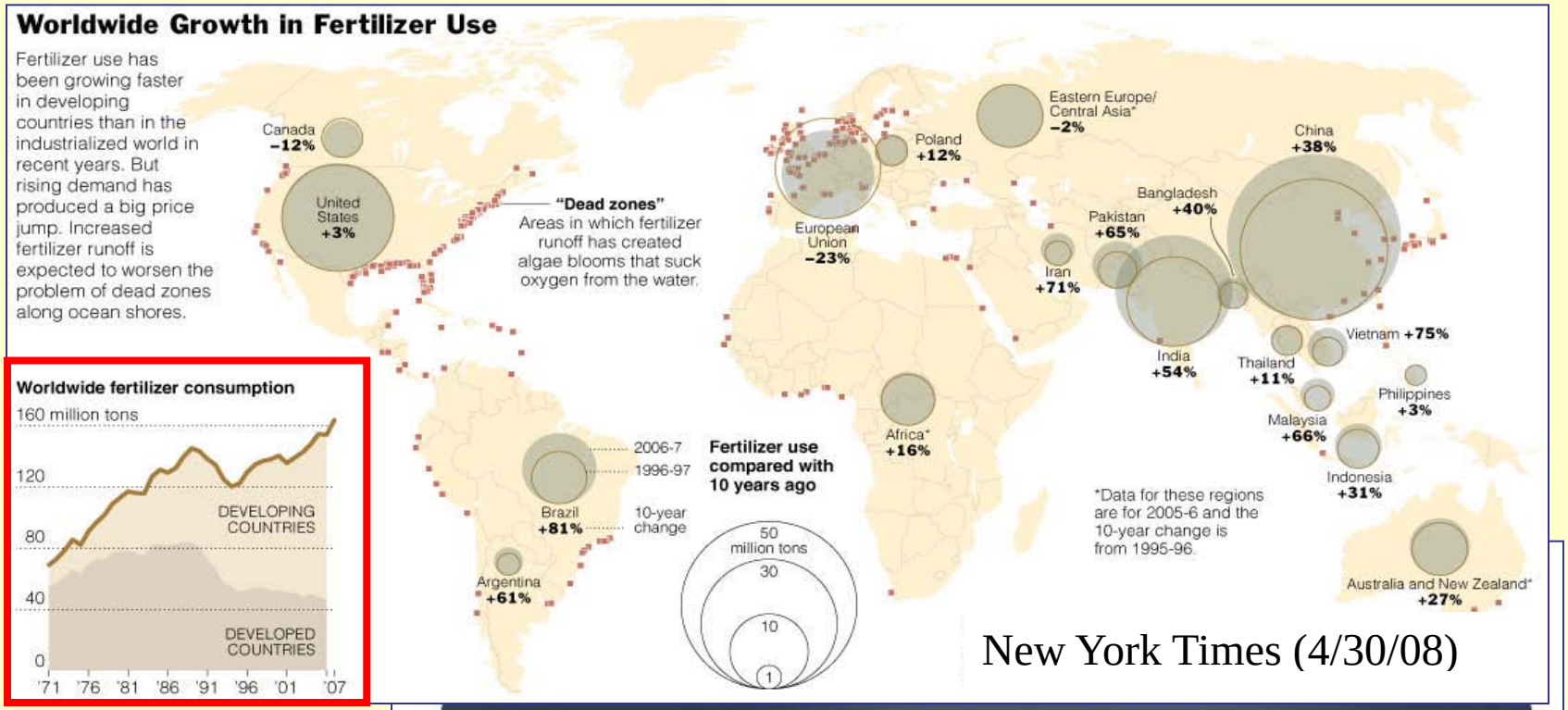



(modified from Howarth et al. 2005)

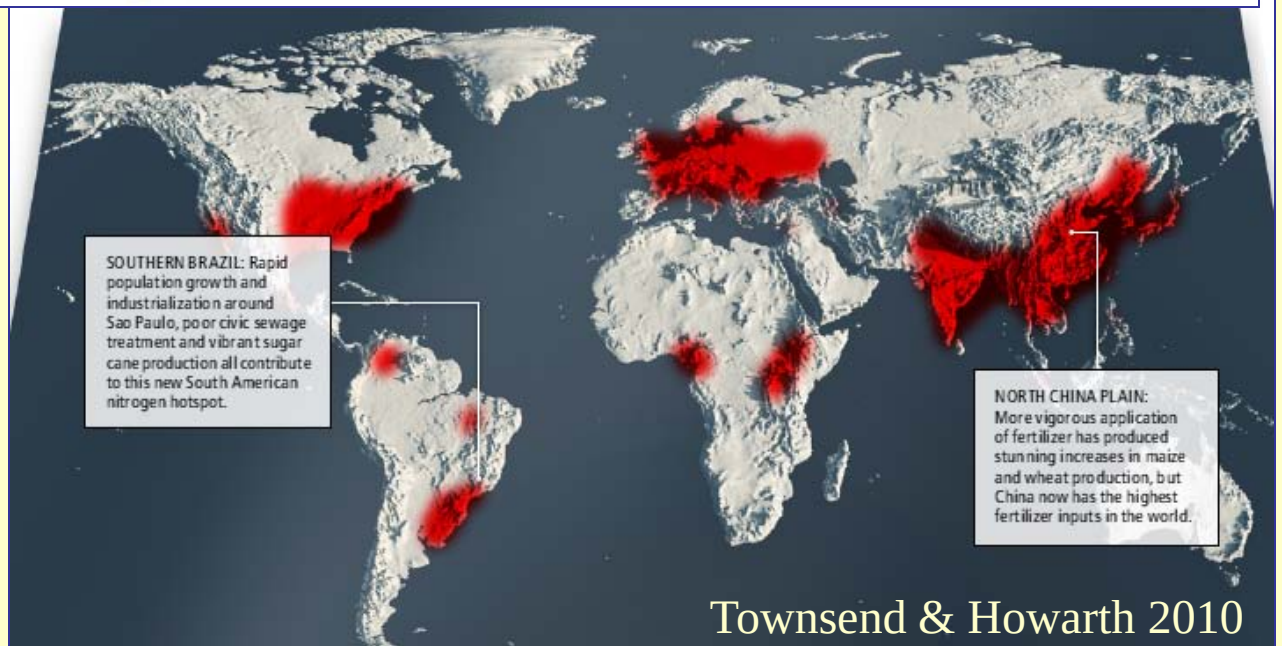
**Regional scale perspective important for nutrients.**

**Changes are driven by global energy and agricultural policies.**

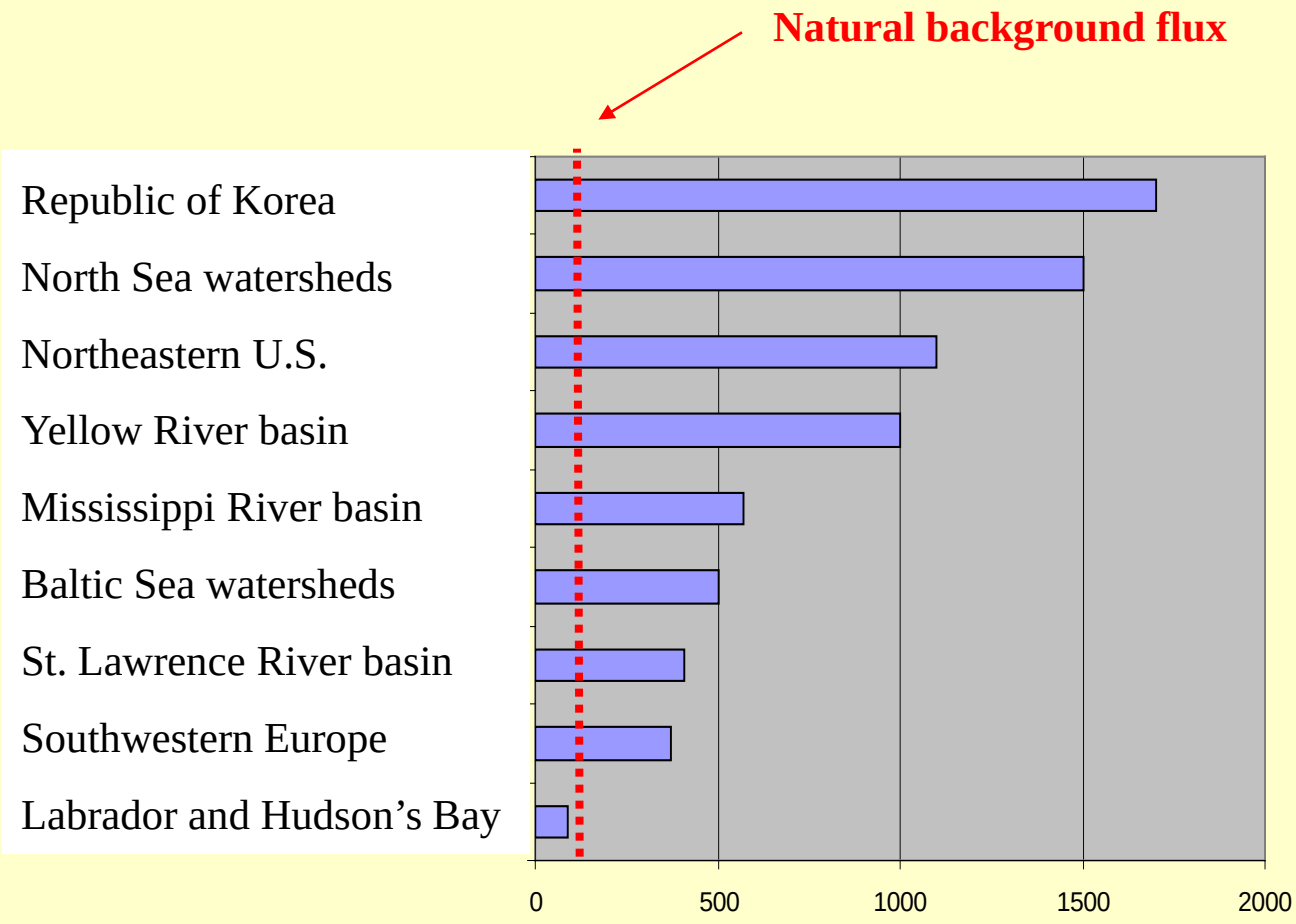
**But with exception of $N_2O$, nutrient cycles are altered at local to regional scales, not global scales, and effects are manifested at these local to regional scales.**



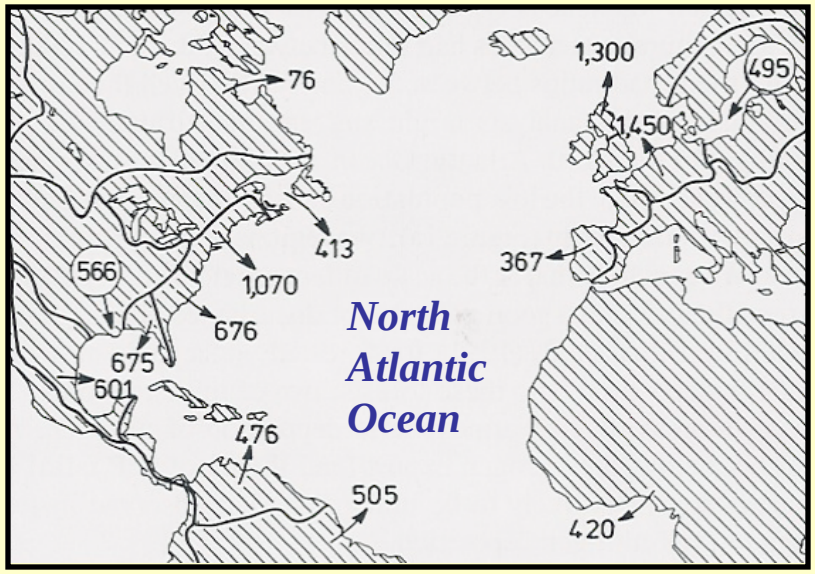

New York Times (4/30/08)



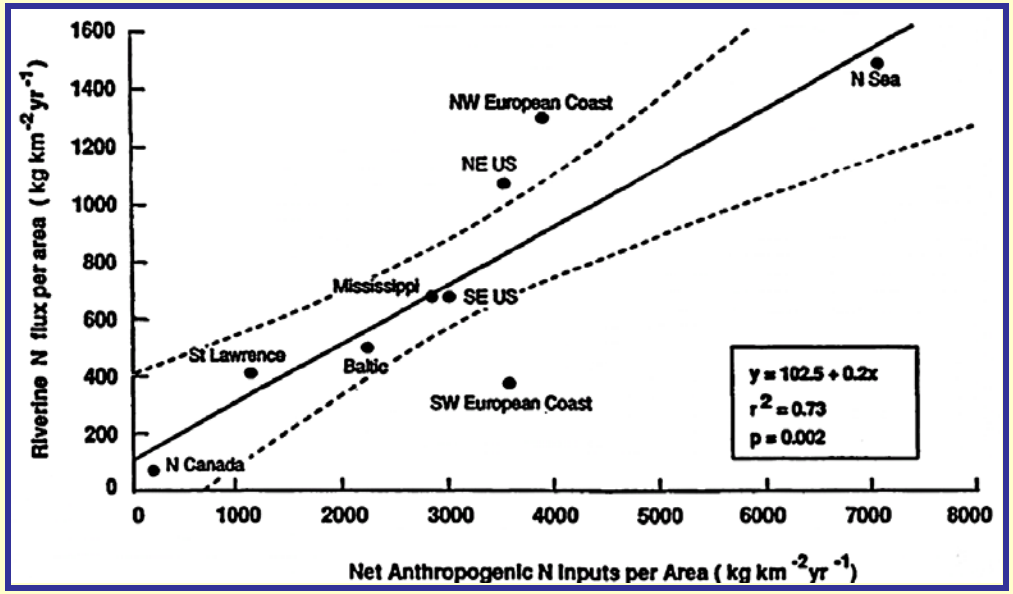

Townsend & Howarth 2010




***Flux of nitrogen from the landscape to coastal oceans in rivers for contrasting regions of the world in the temperate zone (kg per km$^2$ of watershed area per year; from Howarth et al. 2005).***




Kg N km$^{-2}$ year$^{-1}$



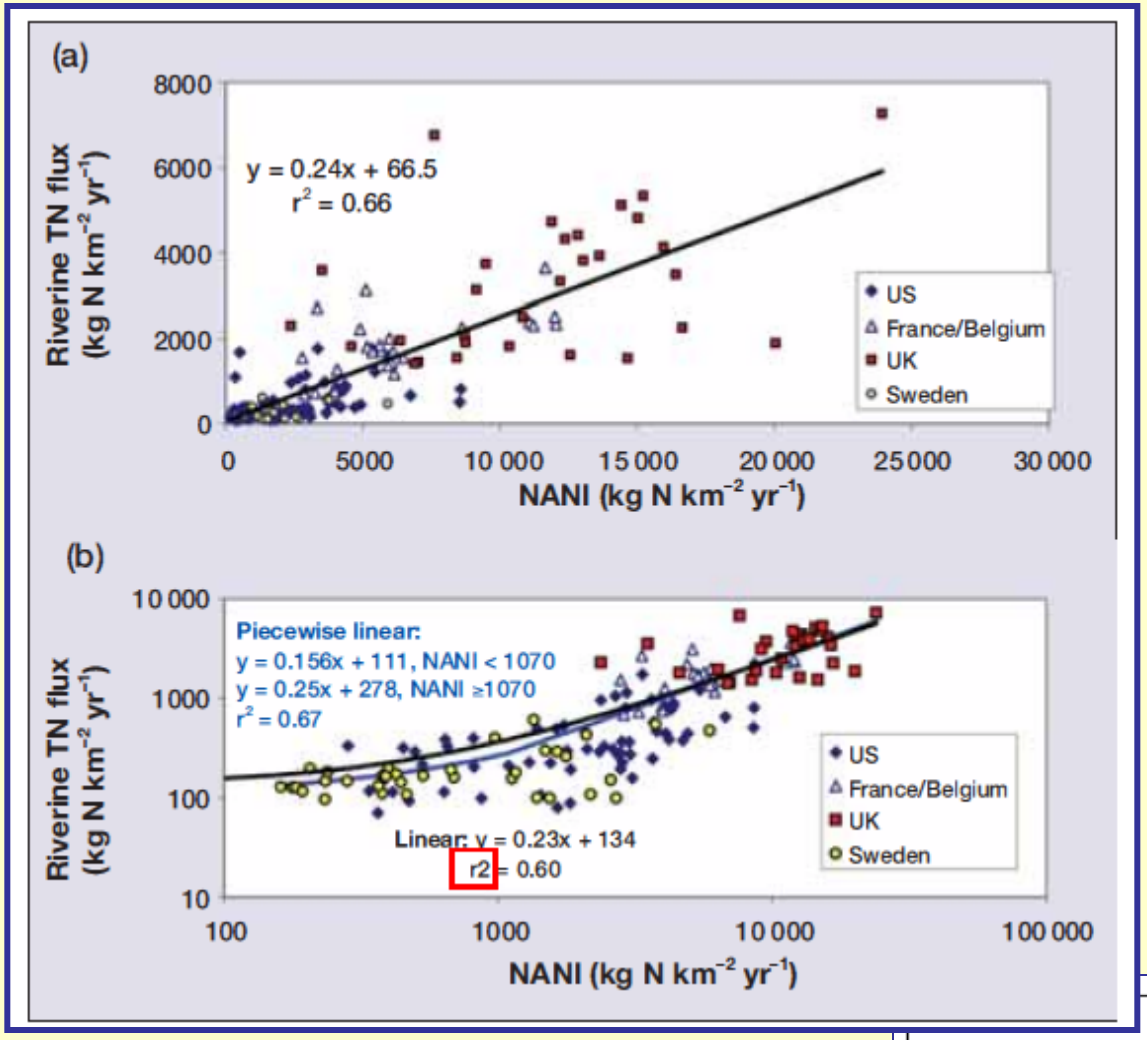

| | $NO_y$ deposition | Fertilizer | N fixation by crops | Net import (+) or export in foods | Total |
|---|---|---|---|---|---|
| North Canada rivers | 70 | 160 | 30 | -50 | 210 |
| St. Lawrence basin | 610 | 330 | 260 | -30 | 1170 |
| NE coast of US | 1200 | 600 | 750 | 1000 | 3550 |
| SE coast of US | 1020 | 1170 | 370 | 450 | 3010 |
| Eastern Gulf of Mexico | 760 | 1260 | 250 | 580 | 2850 |
| Mississippi River basin | 620 | 1840 | 1060 | -1300 | 2220 |
| Baltic Sea drainages | 480 | 1730 | 30 | 20 | 2220 |
| North Sea drainages | 1090 | 5960 | 5 | -5 | 7050 |
| NW European coast | 1090 | 2870 | 50 | -320 | 3700 |
| SW Eutropean coast | 460 | 3370 | 15 | -65 | 3780 |

# NANI

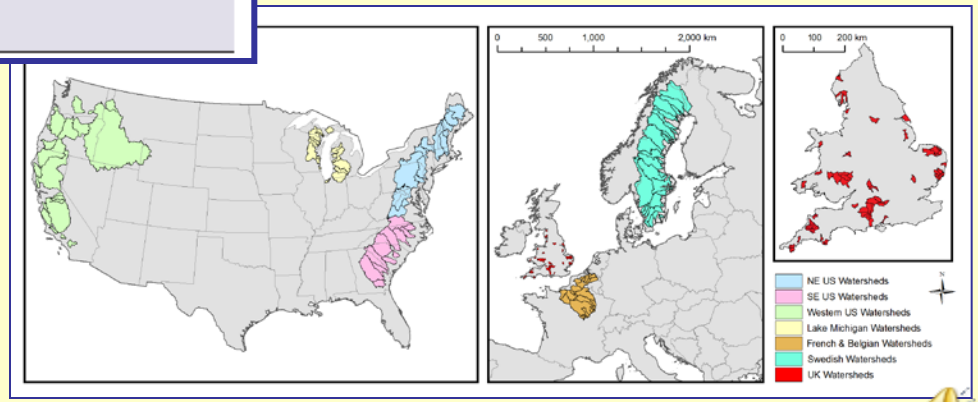
## (net anthropogenic N inputs)

**International SCOPE N Project**
**(Howarth et al. 1996)**

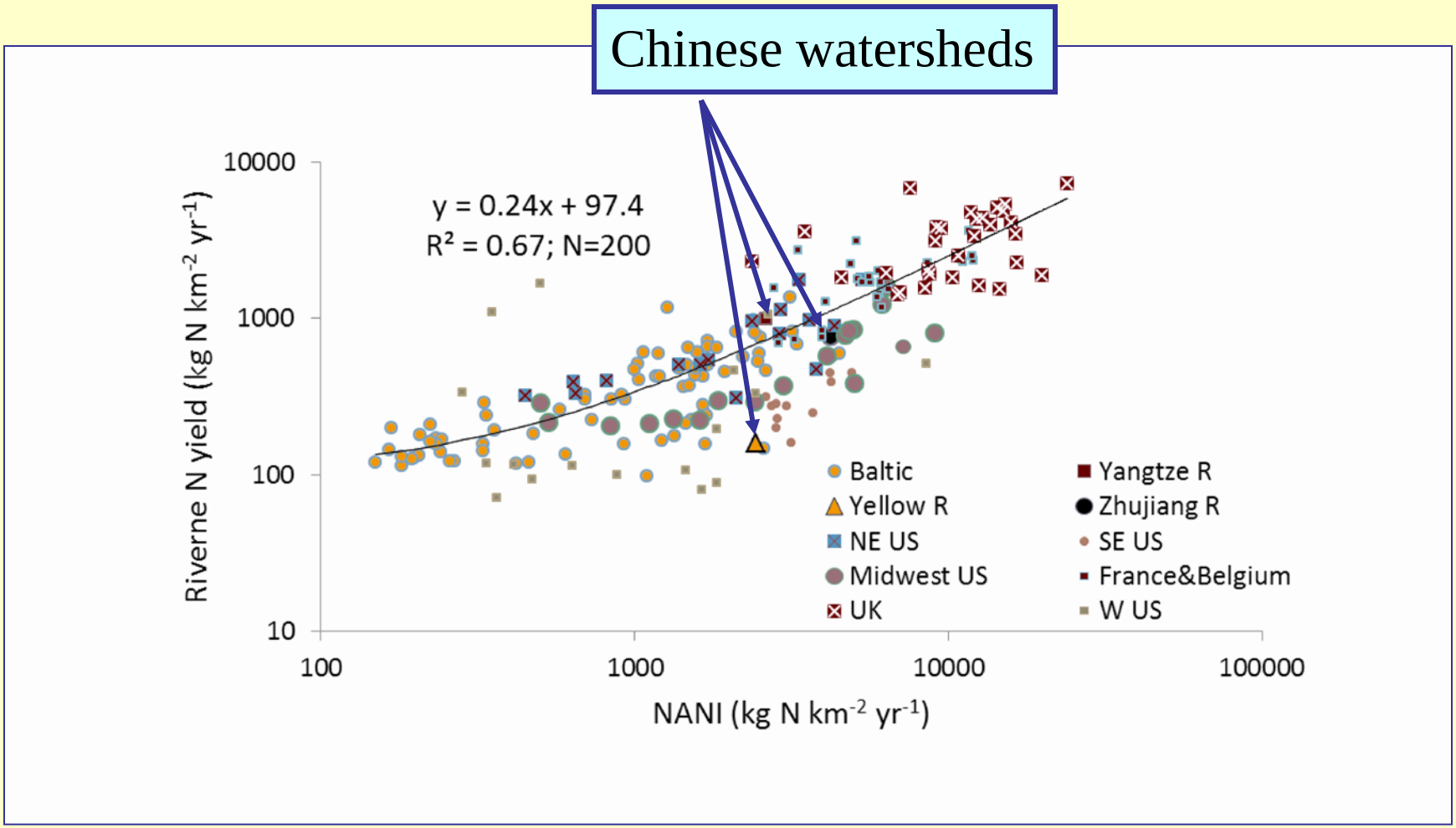
(Howarth et al. 2012)



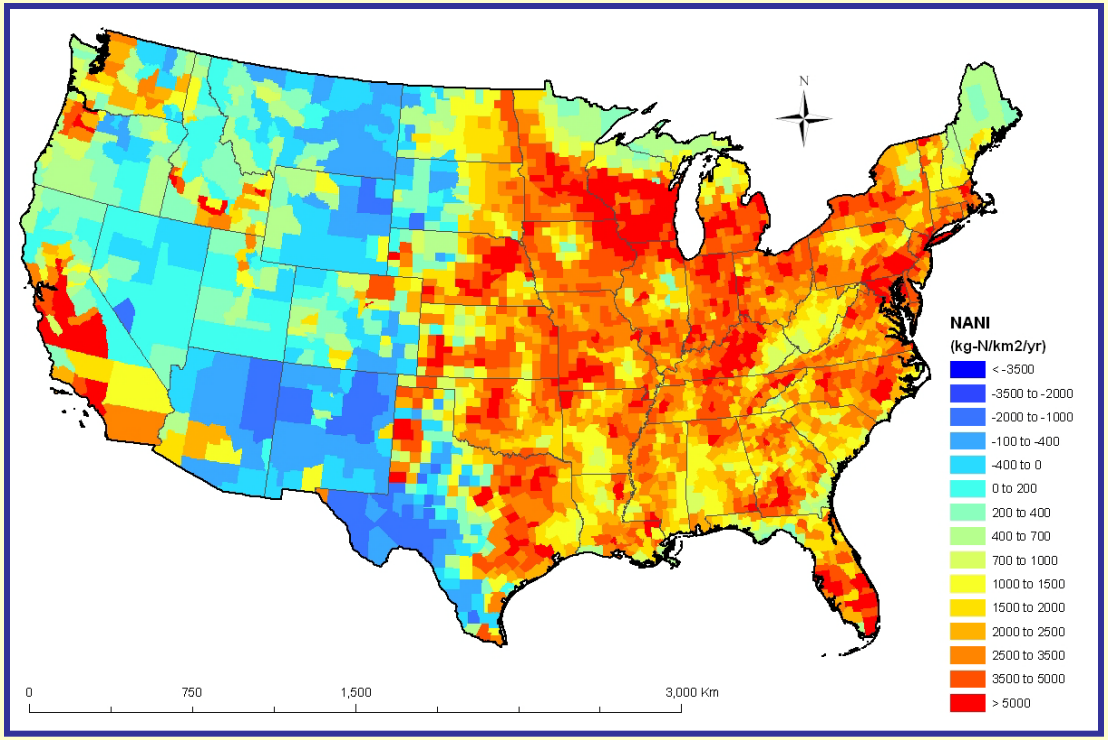

**~ 150 watersheds on two continents**

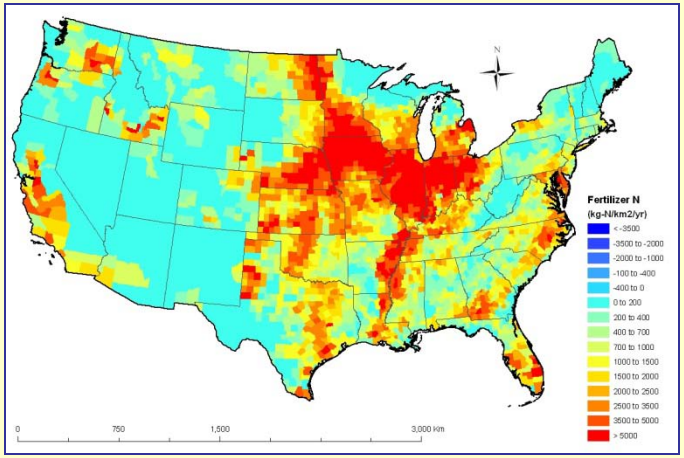


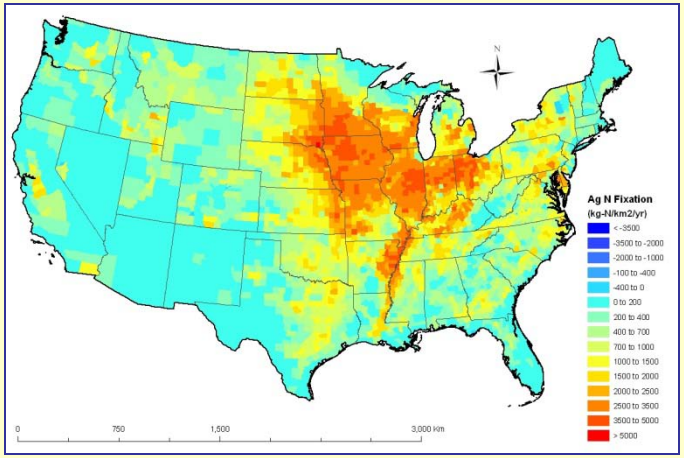

**~ 25% of NANI exported to coastal oceans on average from 150 watersheds in Europe and the US**

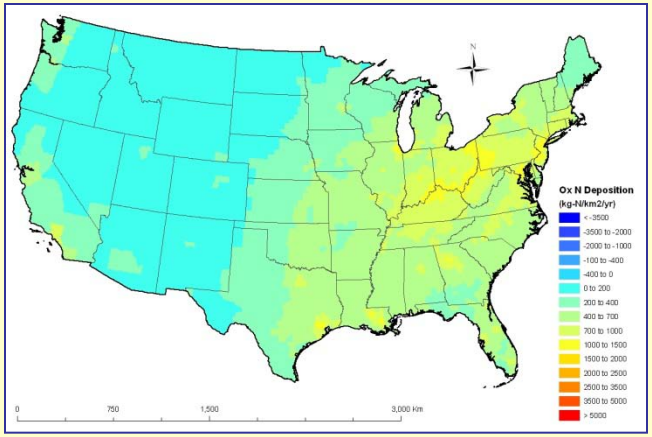


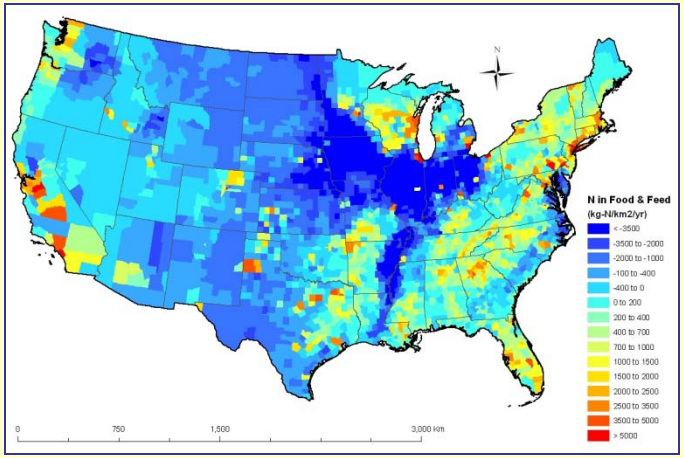

Swaney et al. 2012



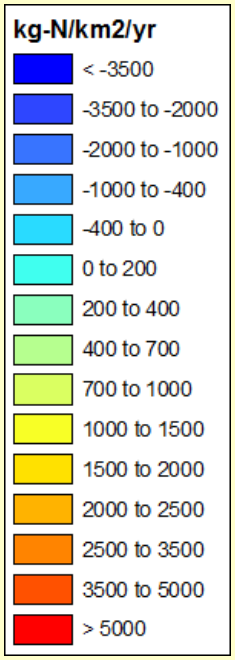



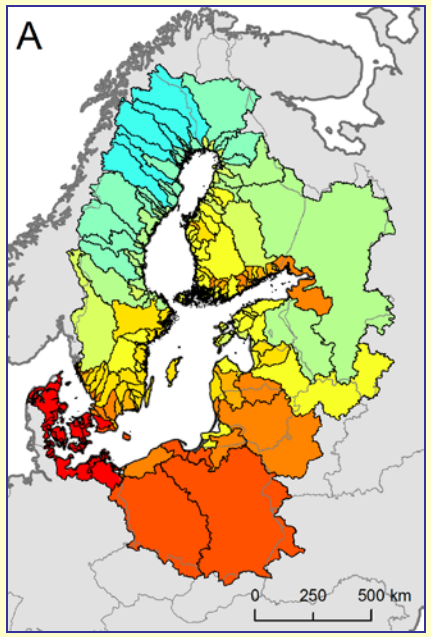



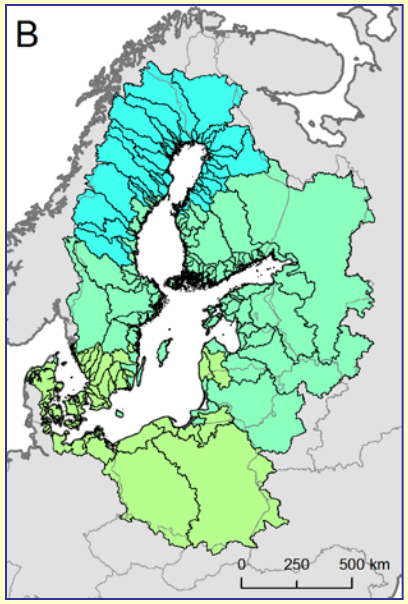

**(Hong et al. 2011)**



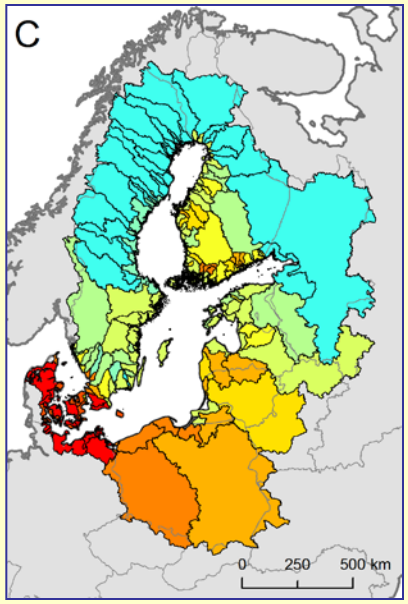




# NANI

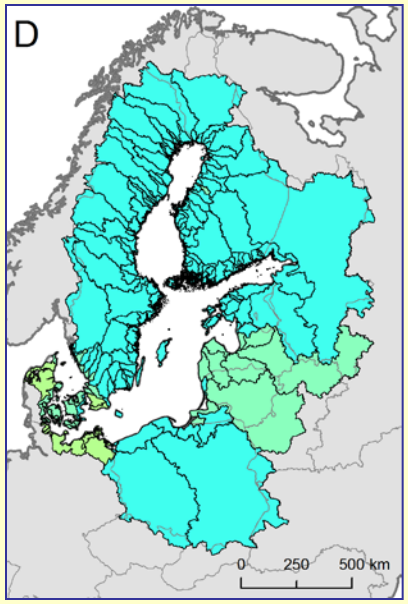
Hong et al., 2012



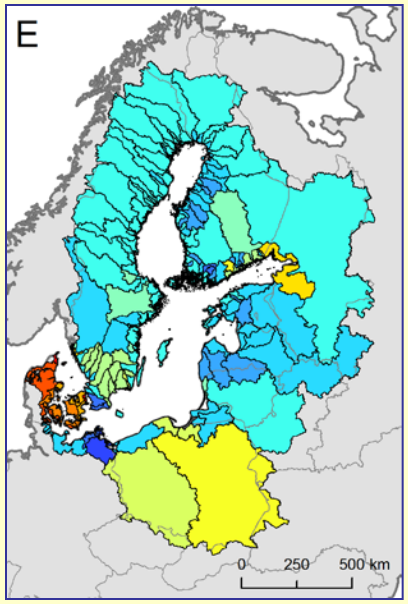

NOy deposition




Fertilizer




Ag N fixation




Net food & feed

# Per capita NANI by region (partial analysis)

| Region | Nutrient fertilizer consumption (kg N/capita, 2009) | NOx Emission (kg N/capita, 2000) | N fixation and net flux of N in food and feeds | Sum of Reactive Nitrogen (kg N per capita) | Consumption relative to safe operating boundary |
|---|---|---|---|---|---|
| Africa | 2.5 | 0.9 | ? | 3.4 | 0.7 |
| South America | 12.2 | 1.2 | ? | 13.4 | 2.6 |
| Southeast Asia | 12.7 | 0.7 | ? | 13.4 | 2.6 |
| India | 13.0 | 0.5 | ? | 13.5 | 2.6 |
| North America | 35.9 | 9.6 | ? | 45.5 | 8.9 |
| Europe | 18.4 | 3.1 | ? | 21.5 | 4.2 |
| East Asia | 24.3 | 1.2 | ? | 25.4 | 5.0 |
| Australia | 30.8 | 7.9 | ? | 38.8 | 7.6 |
| Other | 10.5 | 0.6 | ? | 11.0 | 2.2 |
| **Global** | **15.4** | **1.5** | **4.6** | **21.5** | **4.2** |

UNEP Sustainable Resource Use Panel (2011 draft)

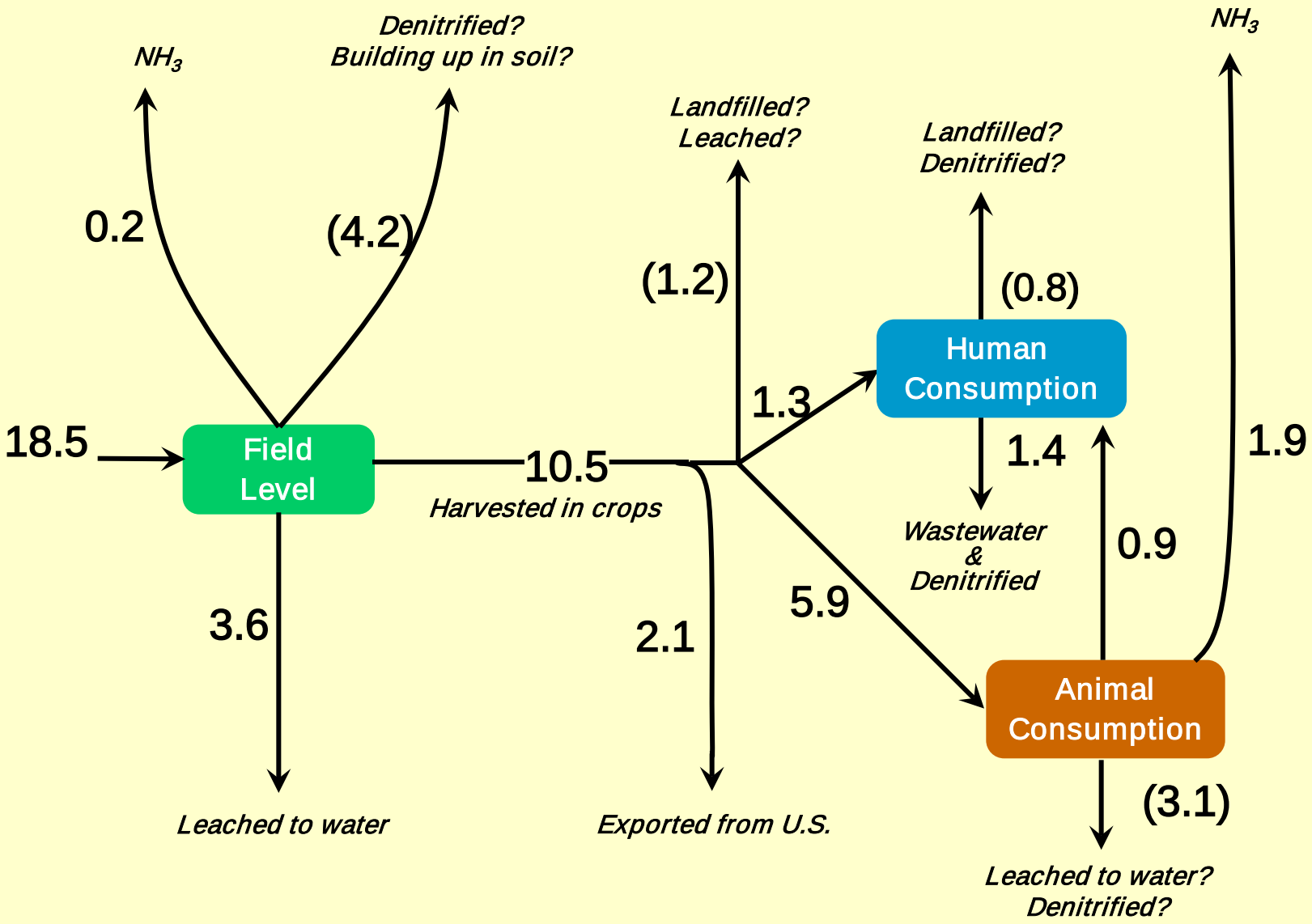
# Technical solutions for nitrogen pollution:

- Agricultural fields: reduce fertilizer amount and timing; change cropping systems; plant winter cover crops; control drainage seasonally
- CAFOs: treat wastes as society does for human waste
- Vehicle exhaust: tighten emission standards; encourage hybrid vehicles and electric vehicles
- Power plants: tighten emission standards; encourage renewable electricity (solar, wind)
- Sewage treatment: require denitrification treatment

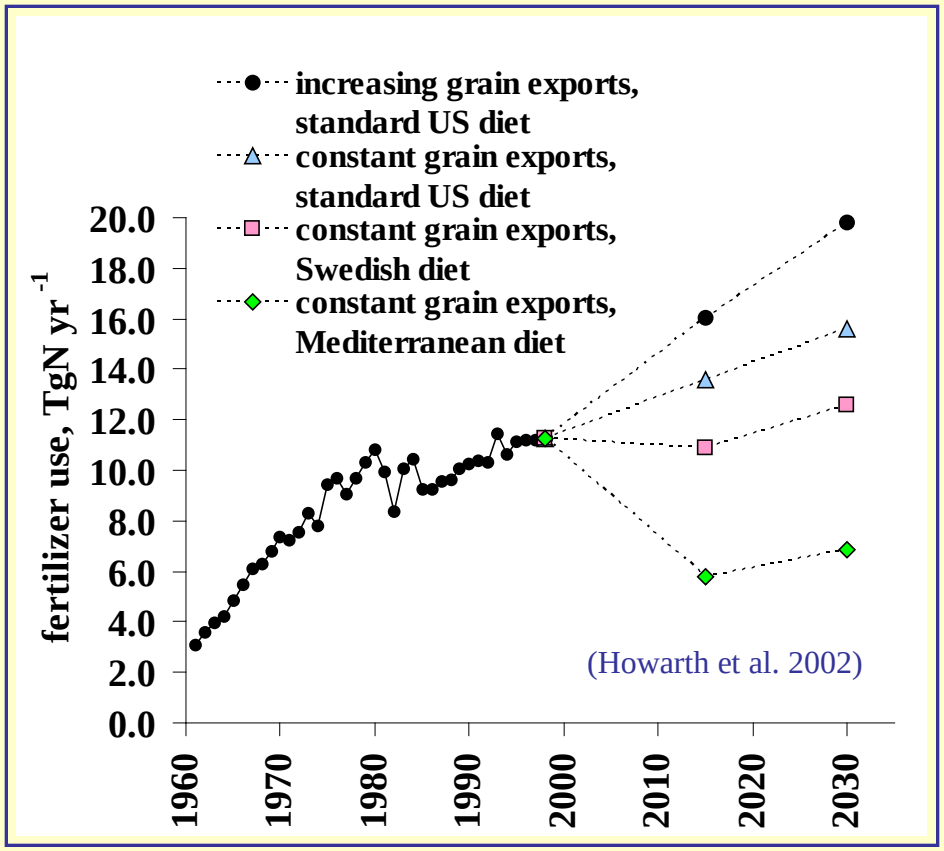
Howarth et al. (2005) Millennium Ecosystem Assessment

**But also think about policy solutions, particularly regarding diet and biofuels….**

# Farm nitrogen balance for US (~1995; Tg per year for entire US)




**(Howarth et al. 2002)**

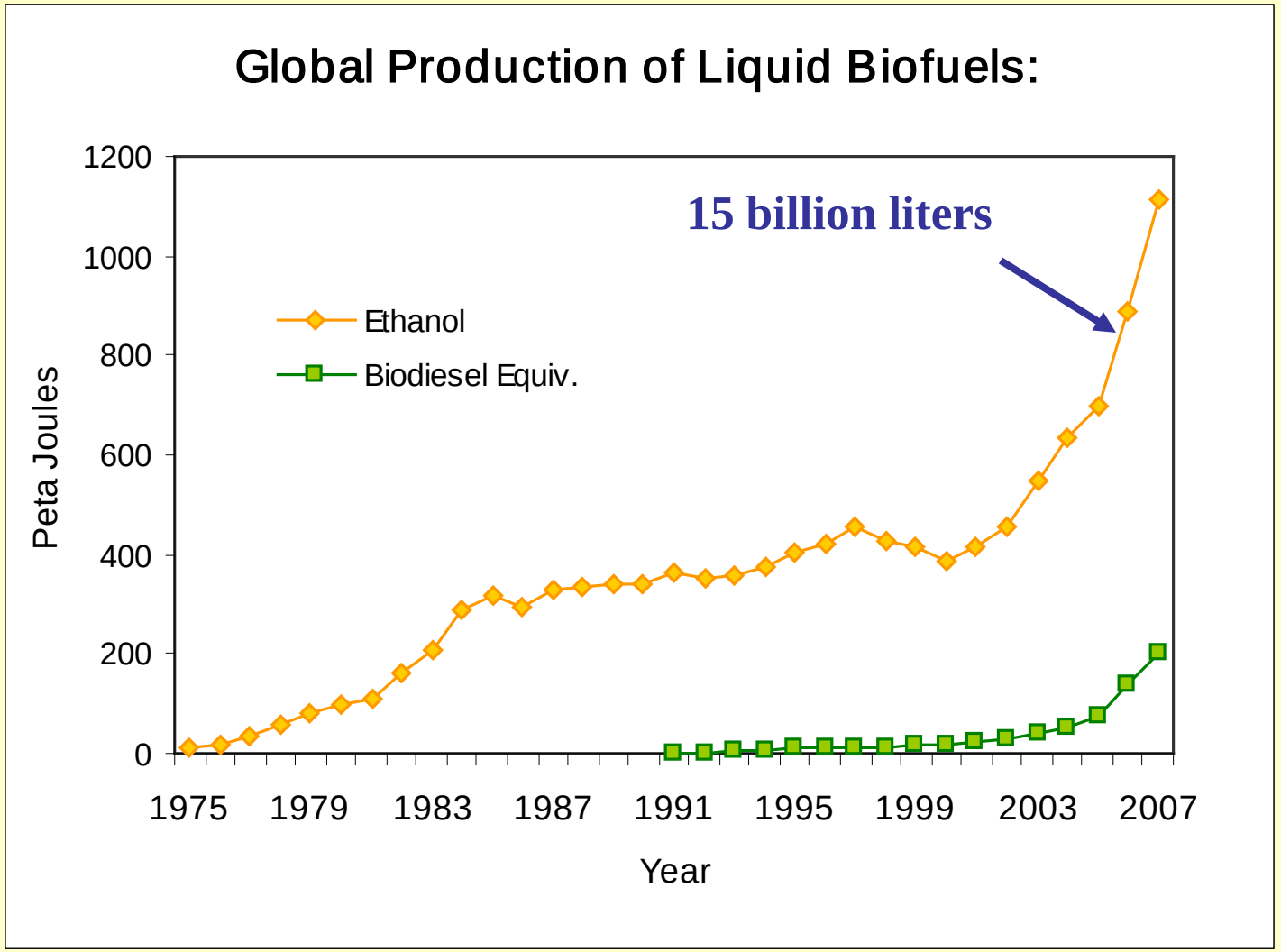



**If everyone in the US ate this:**

**Instead of this:**

**The country would use only 1/3rd as much fertilizer, and would have much less nitrogen pollution!**

SCOPE
Biofuels



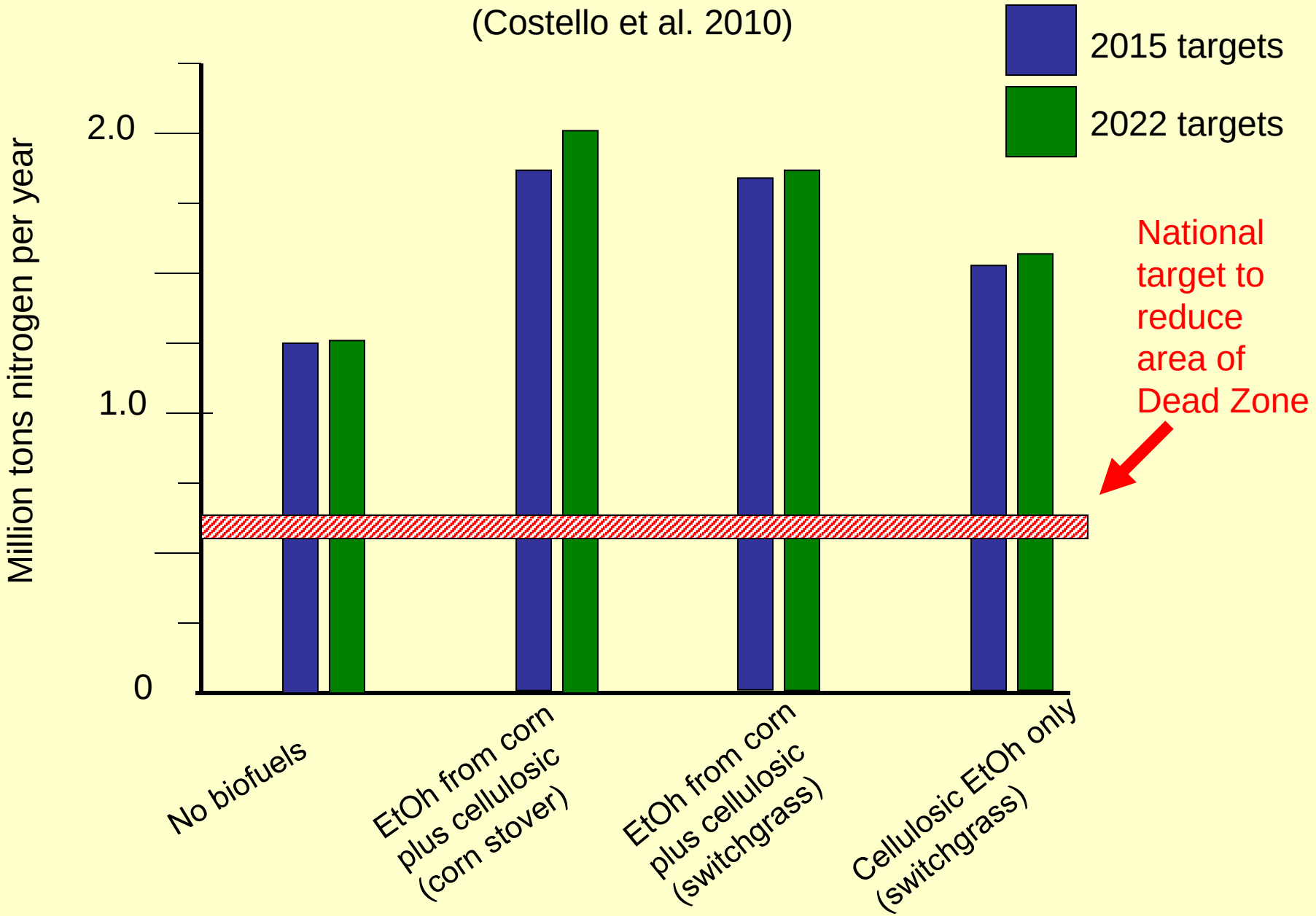

Howarth et al. 2009


**2009: National goal to reduce nitrogen pollution down Mississippi River by 45% to limit size of dead zone.**

Several models indicate national ethanol policy will make this difficult or impossible, and instead nitrogen pollution likely to increase…. 30% to 40% or more (Donner and Kucarik 2008; Simpson et al. 2008, 2009; EPA 2009; Costello et al. 2010)

# Predicted Nitrogen Load from Mississippi River basin to meet US Ethanol Targets

(Costello et al. 2010)



## ***CONCLUSIONS*:**

**Nitrogen is the primary culprit.**

**Nitrogen pollution is growing globally, with agriculture as the primary driver.**

**Technical solutions exist, and can help, often at little cost.**

**But policy considerations of diet (meat!) and energy (liquid biofuels!) are critical.**

Cornell University
College of Agriculture and Life Sciences

# Thanks for invitation to participate!


**Thanks for many collaborators, especially:**

- Dennis Swaney
- Bongghi Hong
- Roxanne Marino
- Christine Costello
- Gilles Billen
- Josette Garnier
- Christoph Humborg
- Alan Townsend



Coastal Hypoxia Research Program


Agriculture, Energy & Environment Program at Cornell University