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# Options for including nitrogen management in climate policy

**J.W. Erisman**

Presented at the 5th International Nitrogen Conference 2010, 3-7 December 2010, New Delhi, India

ECN-L--10-121 DECEMBER 2010

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VU University Amsterdam

# Options for including nitrogen management in climate policy

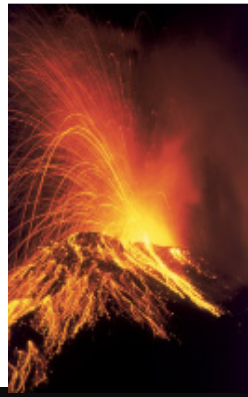
**Jan Willem Erisman**

# Outline of my presentation

- Climate change and nitrogen
- Nitrogen and climate interlinkages
- Options for nitrogen management
- Report, workshop and IPCC
- Conclusions





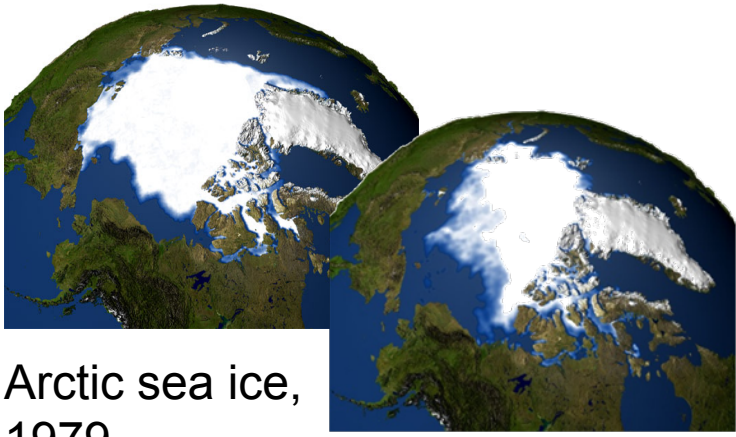


# Nitrogen and climate side event at COP15

- Demonstrate the relevance of nitrogen for climate
- Propose a Special report on *Nitrogen and Climate,* led by TFRN, IGBP, INI, GPNM, ….
- Convention on Long-Range Transboundary Air Pollution Executive Body decision: TFRN to draft a report in December 2010


# The concerns related to Global Warming

Events that are probably linked to global warming

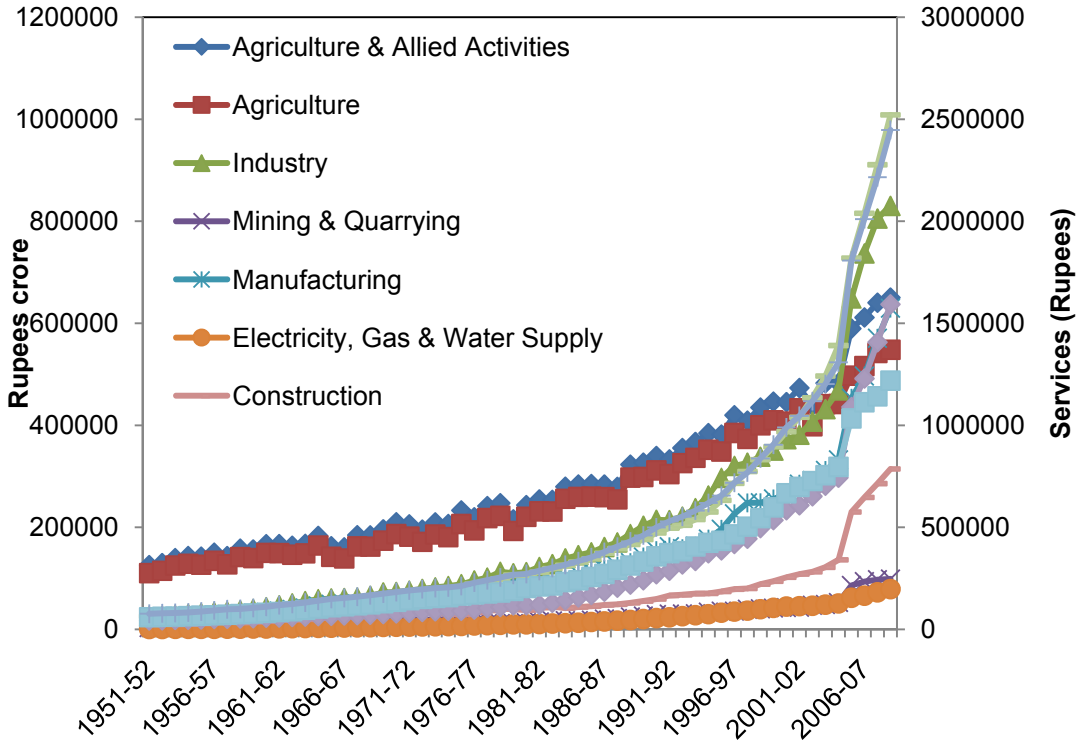


Arctic sea ice, 1979

Arctic sea ice, 2003

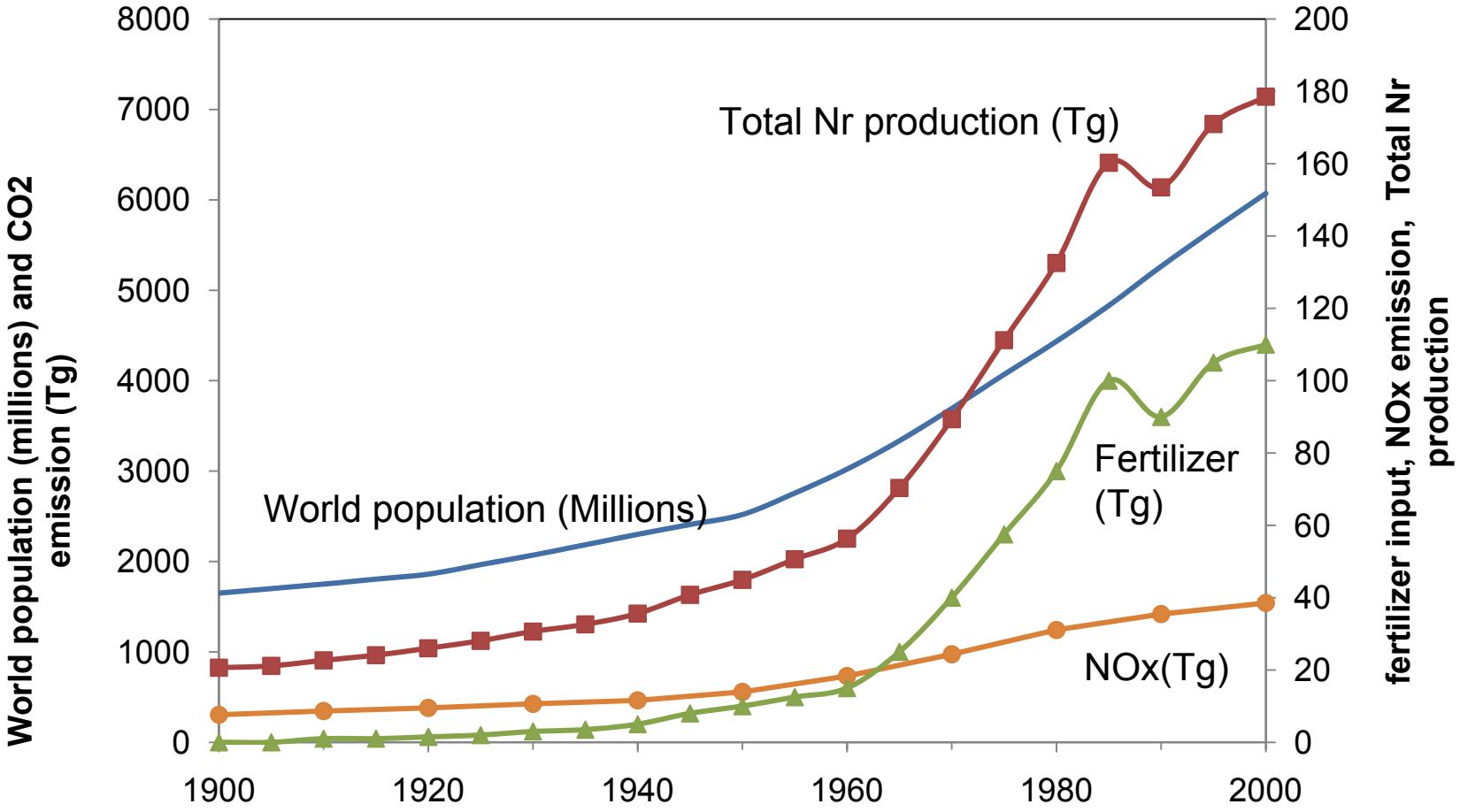
# Changes to the N cycle and GHG emissions have the same dirvers

- population growth and consumption patterns
- increasing demand for energy,
- food, livestock feed and fiber, and
- land-use change

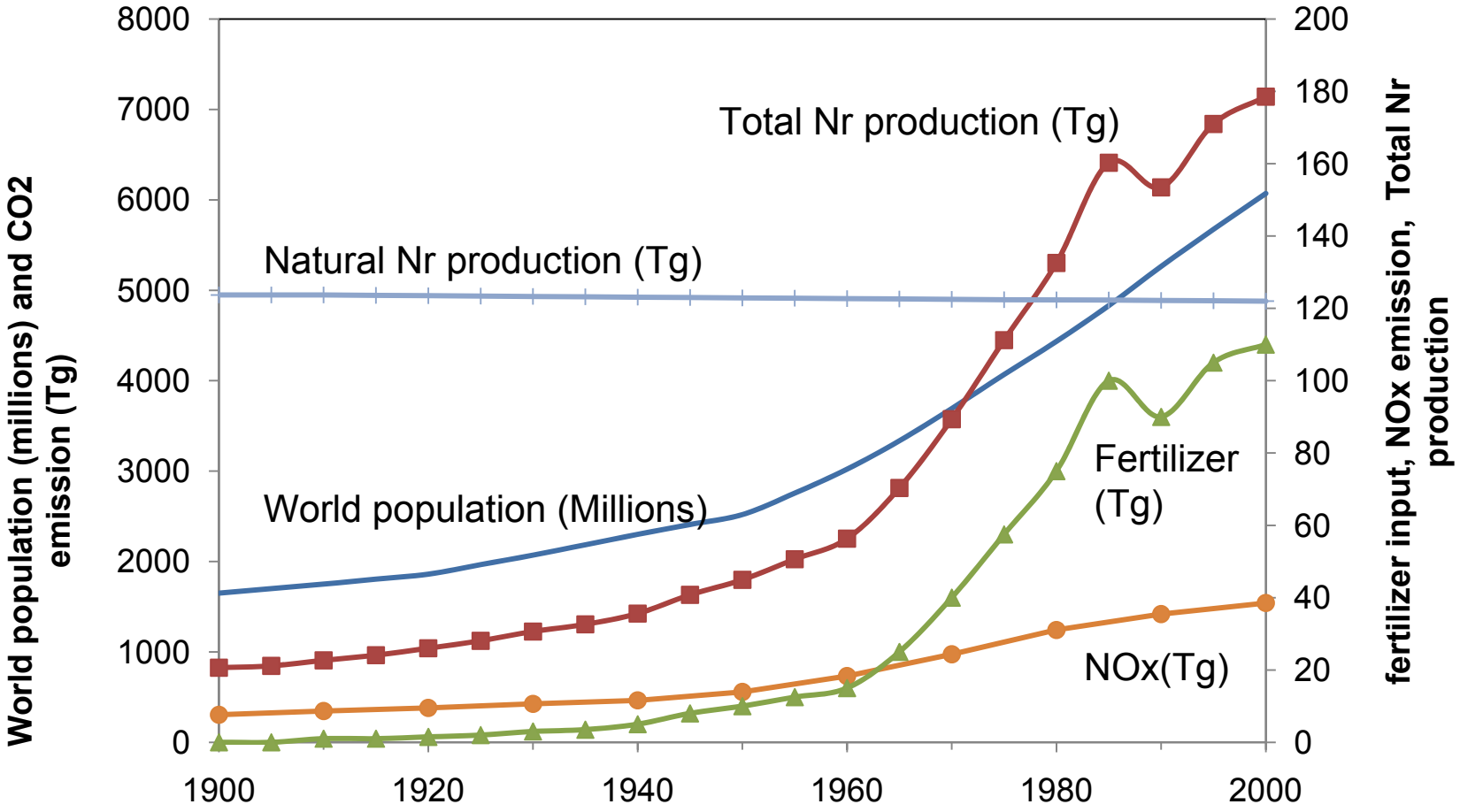



Population: 0.3 to 1,1 billion

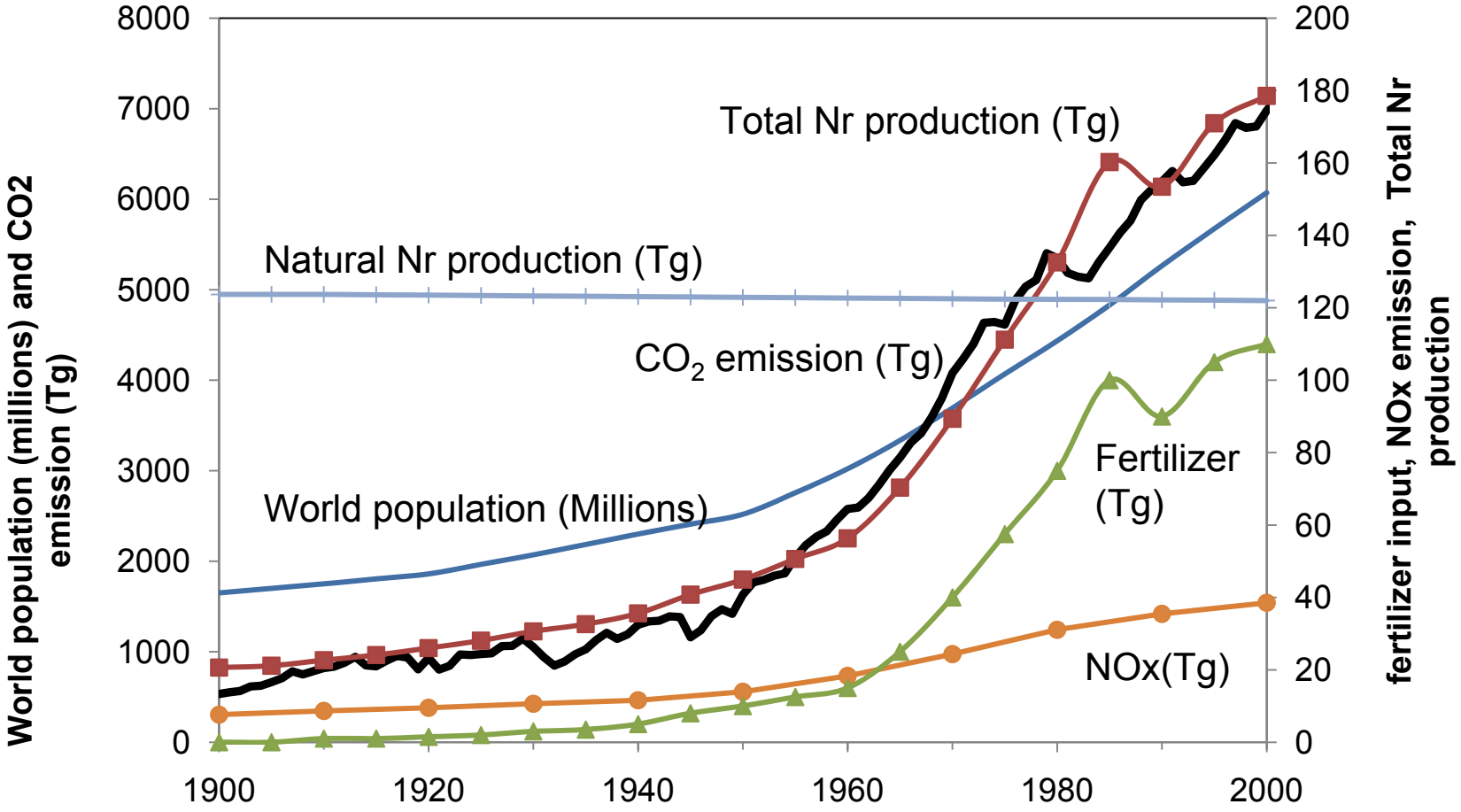
# Reactive N Formation has doubled



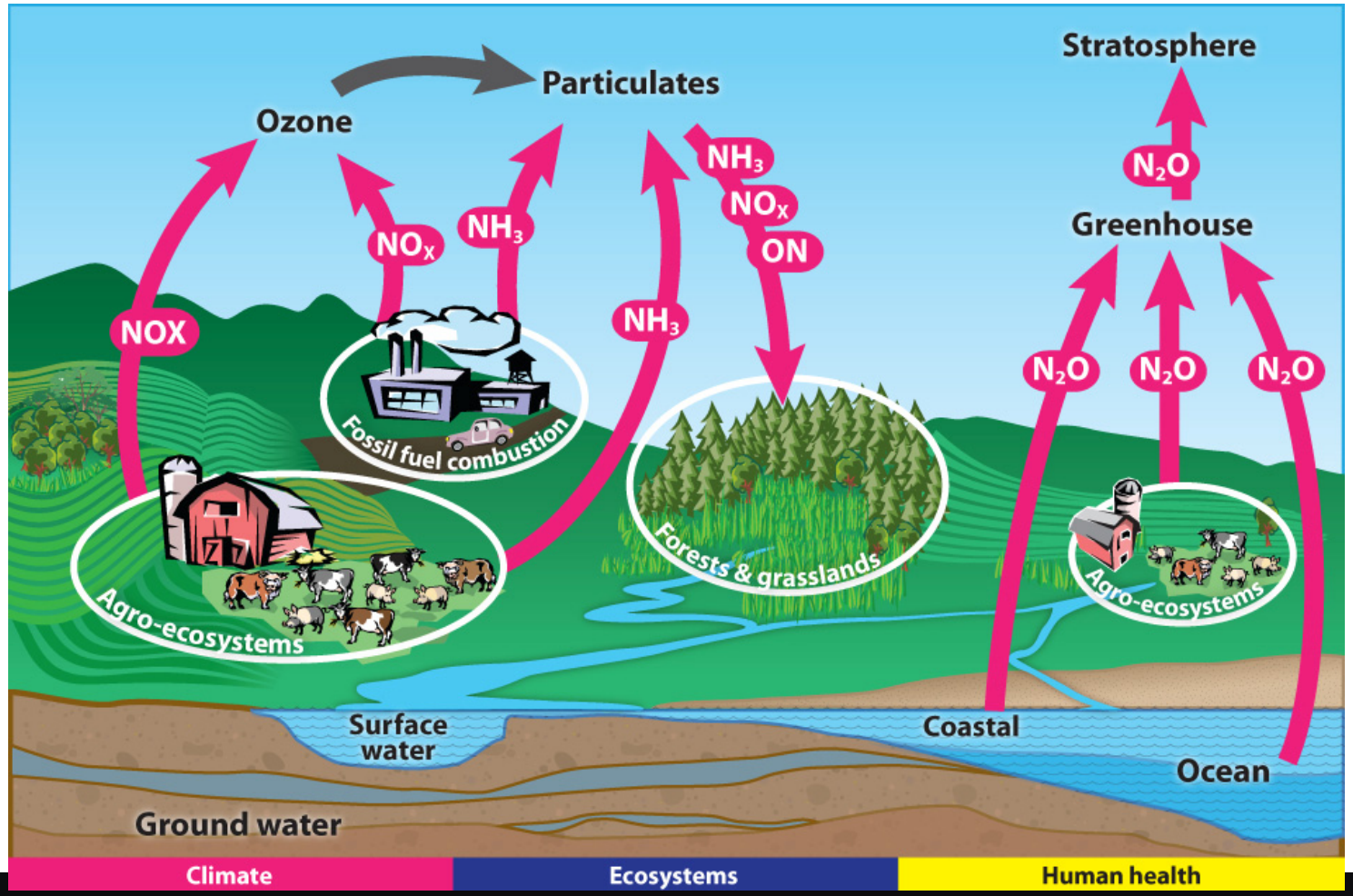
# More nitrogen is now fixed by human activities than by natural processes



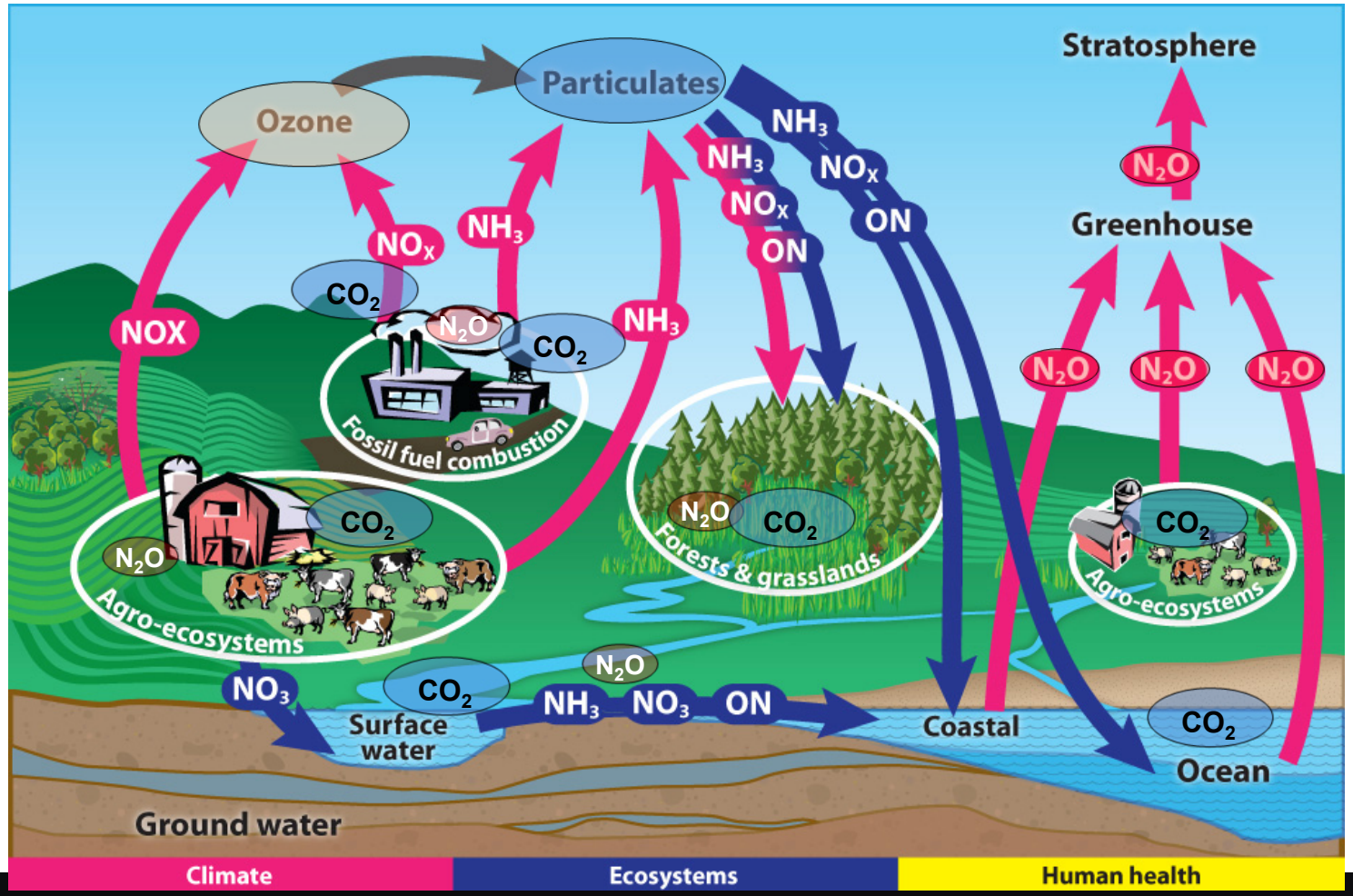
# Trends in Reactive N formation and $CO_2$ emissions are similar



# Nitrogen cascade and climate, ecosystems, human health

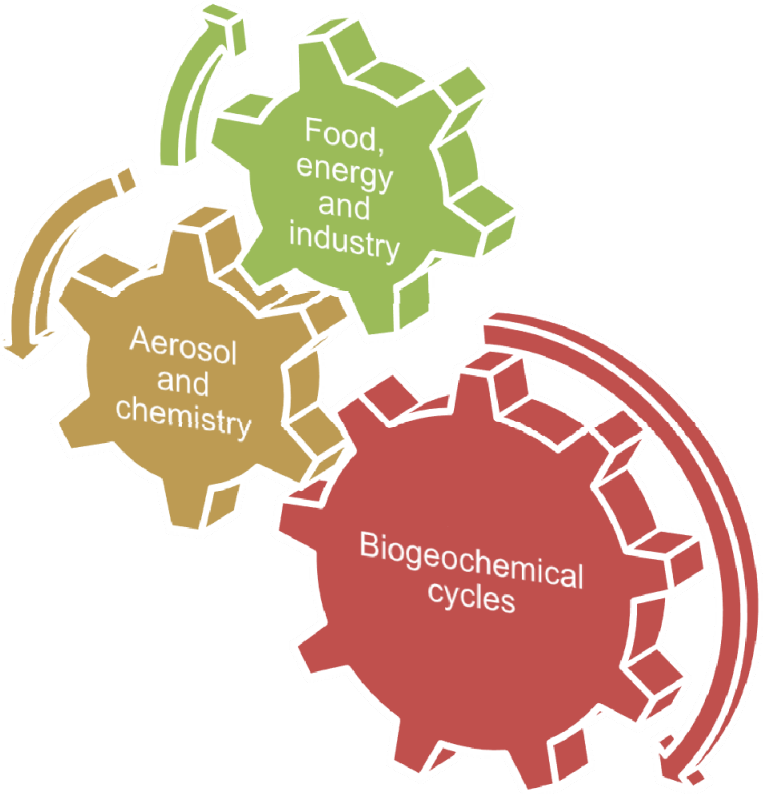


# Nitrogen cascade and climate, ecosystems, human health

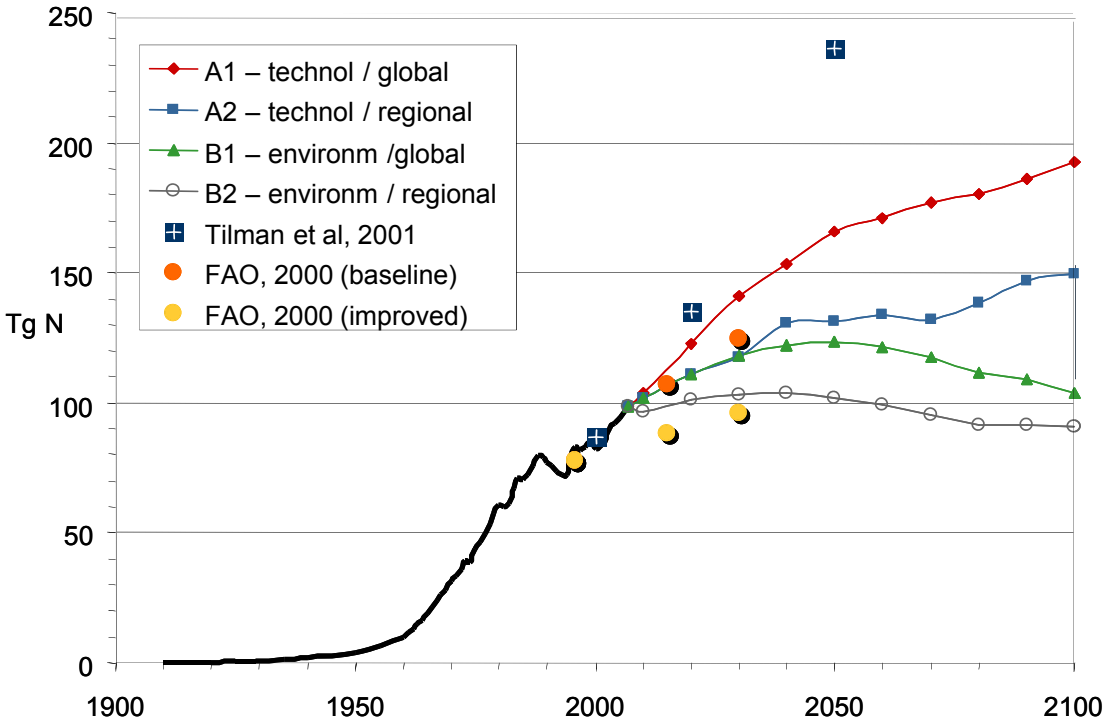


# Different timescales for air pollution, N and climate change

- Climate change is due to long residence time of non-reactive GHG
- Short-lived more reactive components affect the radiative balance: aerosols
- These prove difficult to reduce and emissions sustain
- Continuing build up of N-reservoirs, with long turnover times (and $N_2O$ emission)



# Past and future global N fertilizer consumption




Nr reservoirs will increase for a long time

Erisman et al. (2008)

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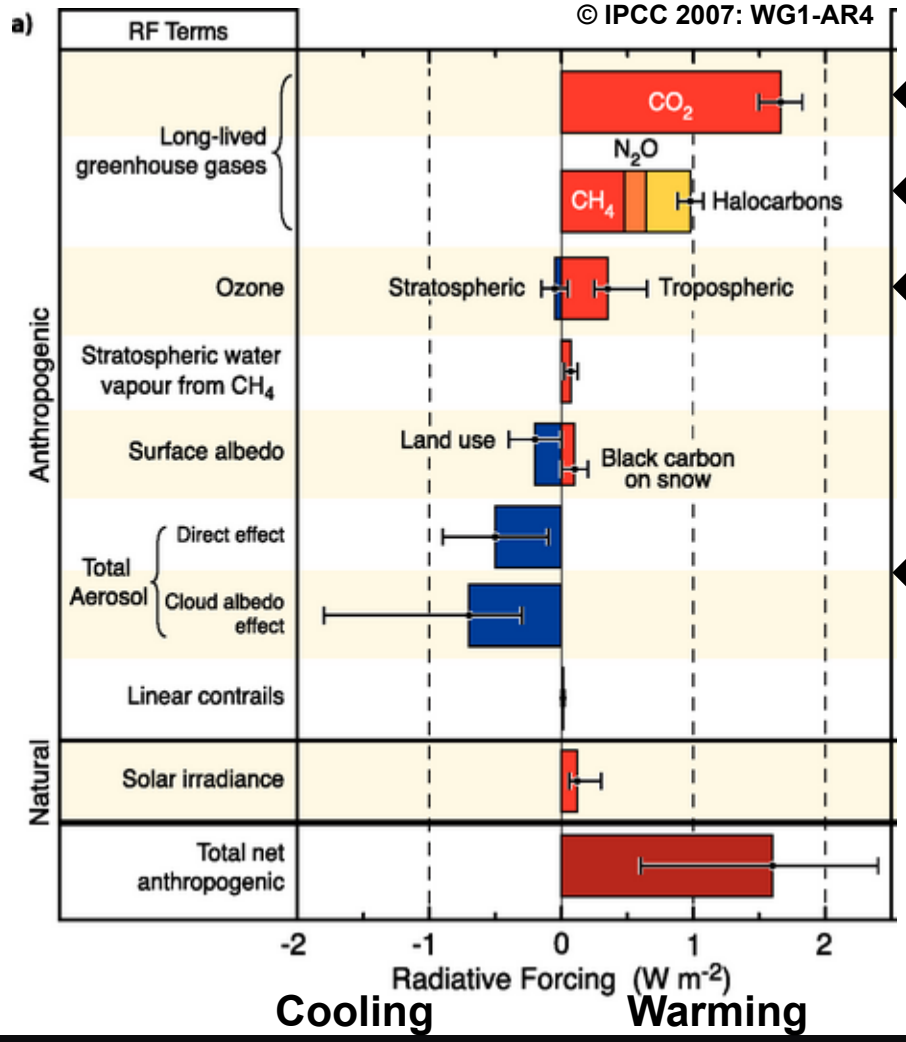
# Nitrogen and climate interlinkages

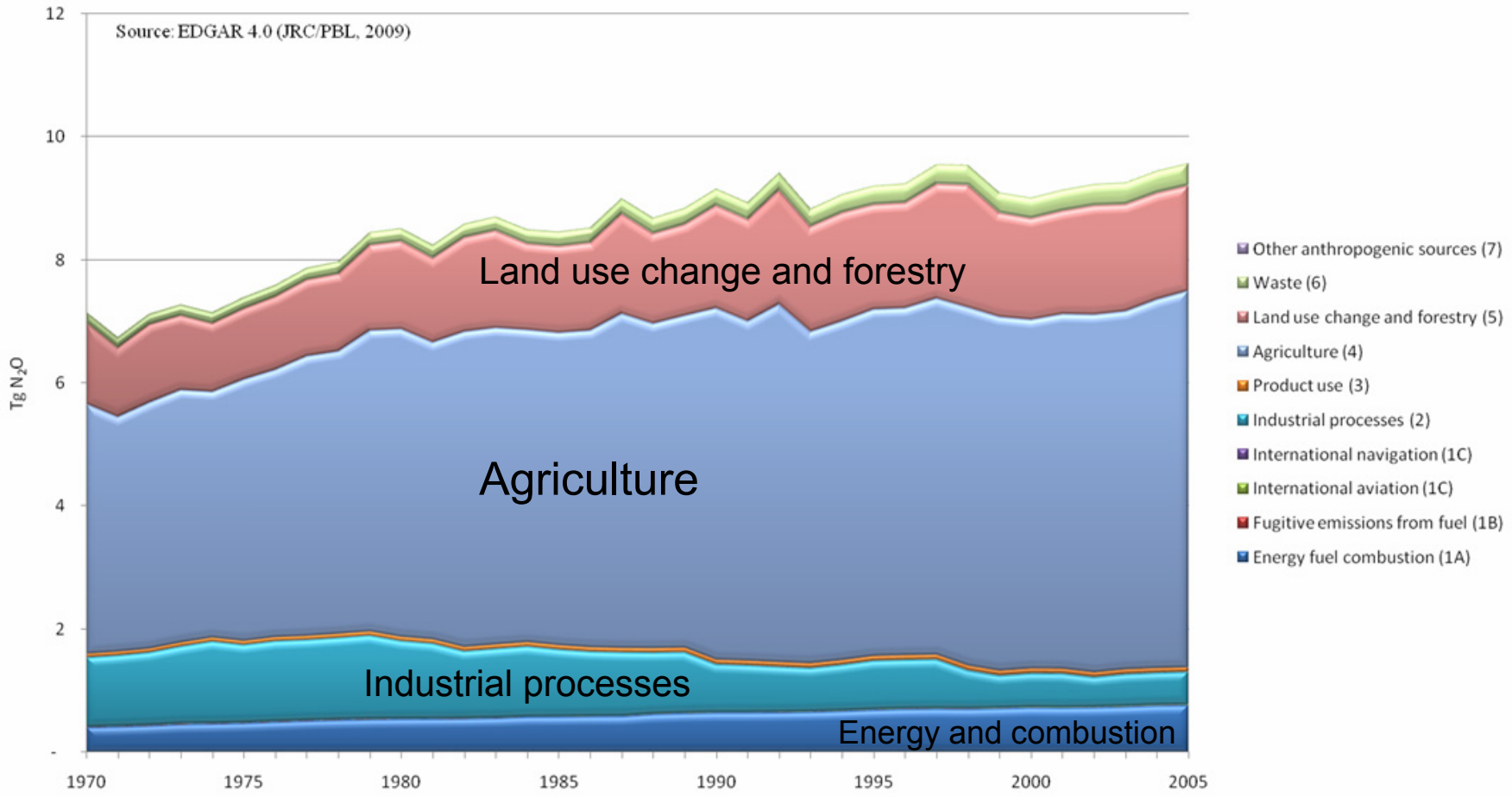
# Effect of nitrogen on global mean radiative forcings




| Nitrogen addition: | Change in radiative forcing |
|---|---|
| Increases land $CO_2$ uptake | (-) |
| $N_2O$ emission: Increases $N_2O$ | (+) |
| $NO_X$ emission: Decreases $CH_4$ | (-) |
| $NO_X$ emission: Increases tropospheric $O_3$ | (+/-) |
| $N_2O$ emission: Decreases stratospheric $O_3$ | (+) |
| $NH_3$ emission: Increases aerosols | (-) |
| $NO_x$ emission: Increases aerosols | (-) |

Nitrogen addition alters directly and indirectly the composition and chemistry of the atmosphere, and changes the radiative forcing. The net radiative forcing varies regionally.

# $N_2O$ is a GHG and emissions increase

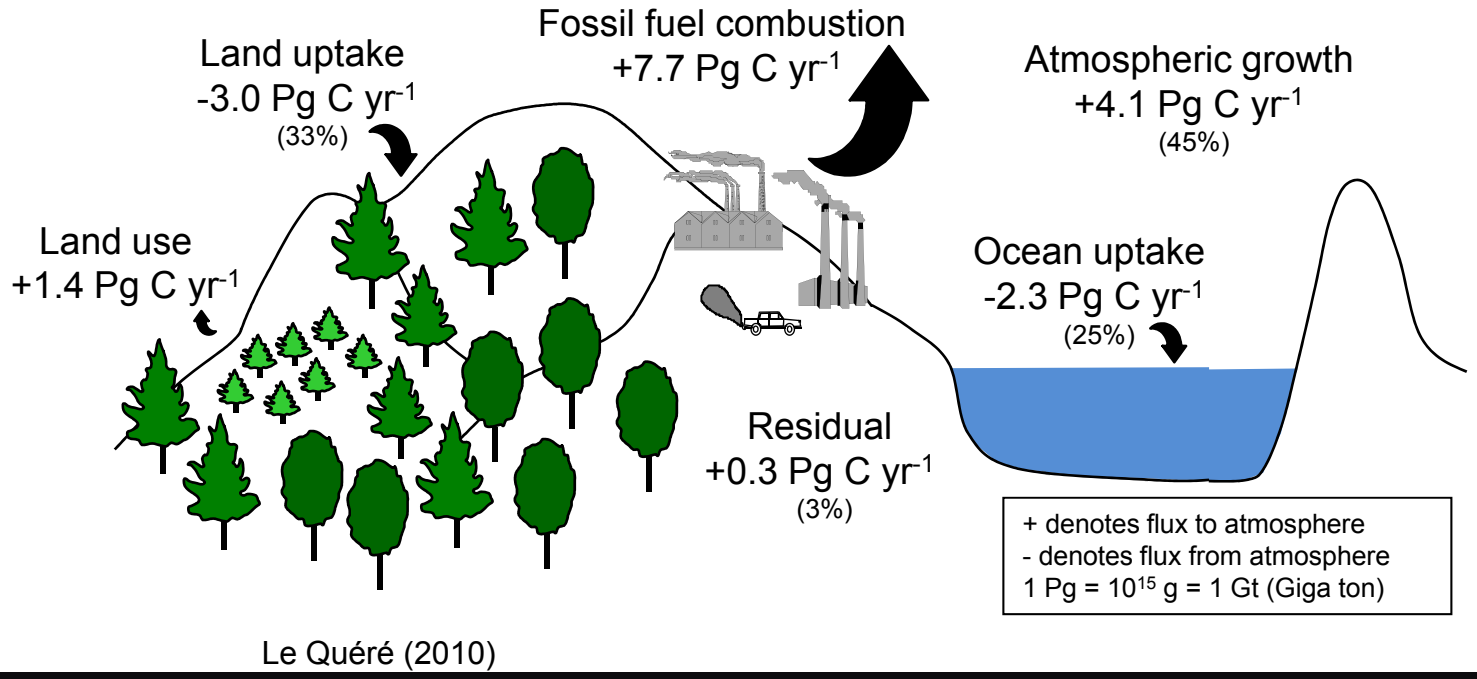


# Nitrogen and the carbon cycle

The capacity of the biosphere to gain carbon depends on nitrogen

- N deposition enhances land/ocean uptake
- Low N restricts $CO_2$ fertilization
- Soil warming enhances N in soil

## Global carbon cycle, 2000-2008




Le Quéré (2010)

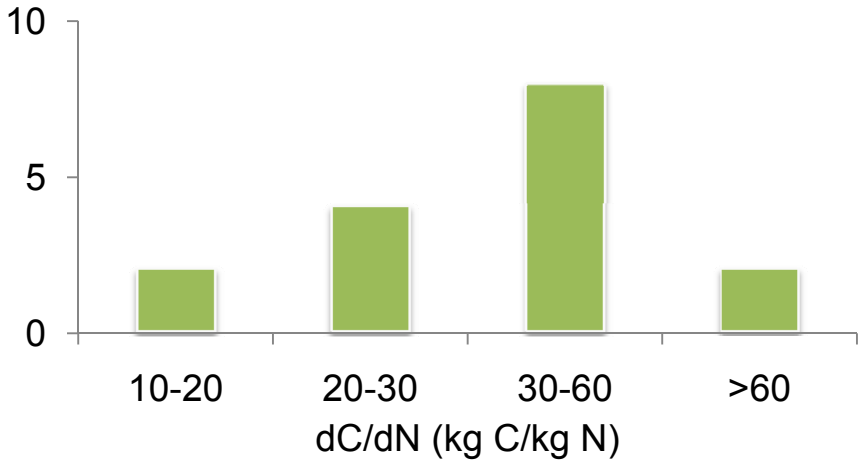
*Data from*

# Nitrogen enhances terrestrial carbon storage

| Ecosystem pool | $dC/dN_{dep}$ (g C/g N) |
|---|---|
| Non-woody plant biomass | 4 |
| Woody plant biomass | 25 |
| | 29 |
| Forest floor and soil | **21** |
| Total | **49** |

N deposition increases terrestrial carbon storage by 0.25 Pg C $yr^{-1}$

Nadelhoffer et al. (1999)




De Vries et al.(2009)

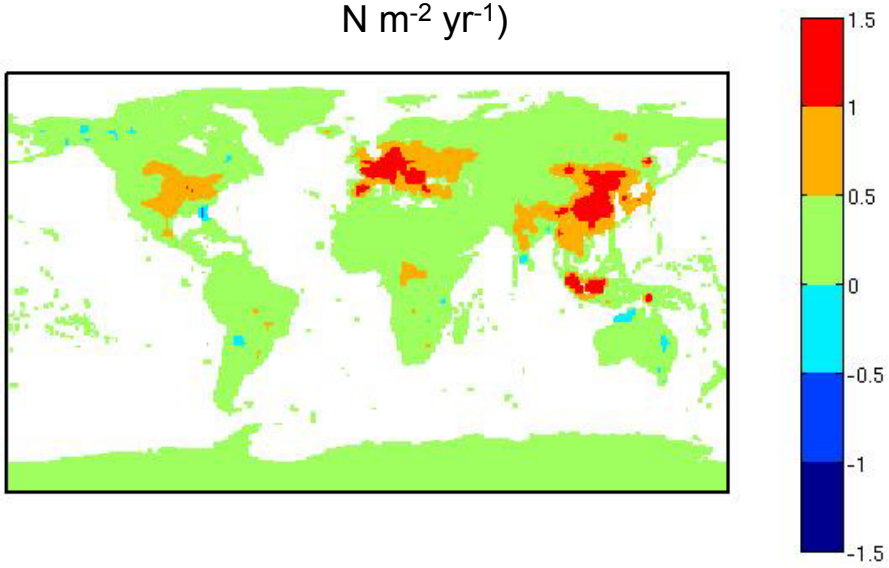
**Forest carbon gain**
$dC/dN_{dep}$ = **24 9 g C/g N** Liu & Greaver (2009)

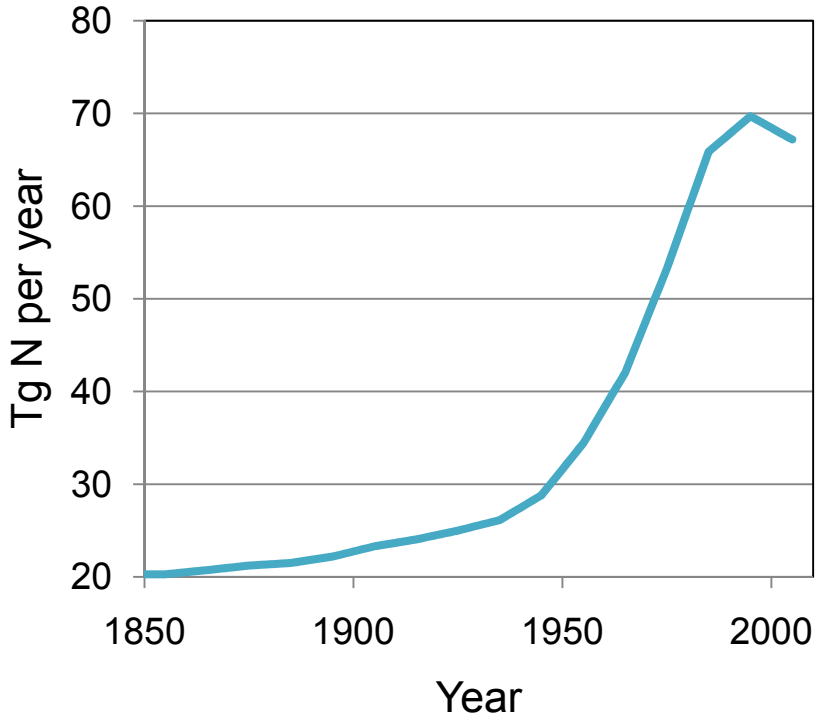
**Aboveground tree carbon gain**
$dC_{tree}/dN_{dep}$ = **61 g C/g N** Thomas et al. (2010)

**Soil carbon gain**
$dC_{soil}/dN_{dep}$ = **19 g C/g N** Janssens et al. (2010)

# Nitrogen deposition and carbon storage

Atmospheric N deposition increase, 1850 to 2005 (g N $m^{-2}$ $yr^{-1}$)

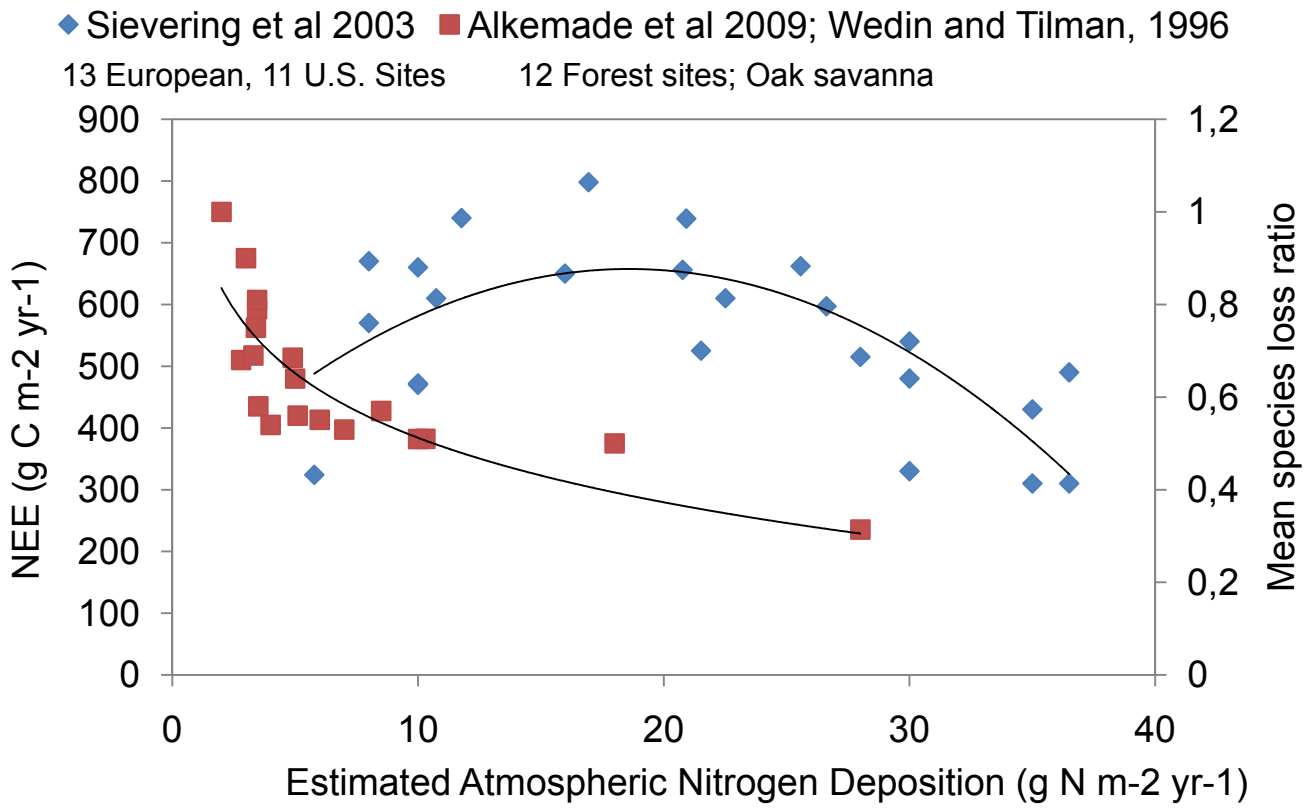


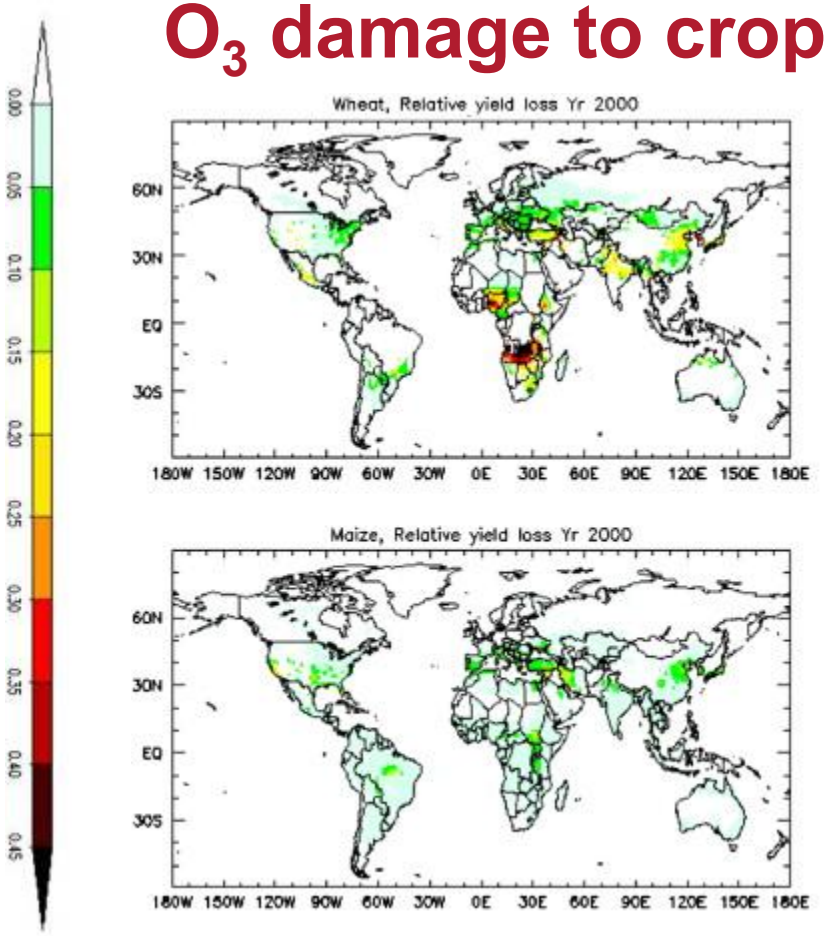

Community Earth System Model (www.cesm.ucar.edu)
Lamarque et al. (2010)

N deposition increased carbon storage by:
~0.3 Pg C $yr^{-1}$ in terrestrial systems
~0.3 Pg C $yr^{-1}$ in marine areas (Bleu Carbon)
Limitations of P, other nutrients ..?

# Effect of N on Net Ecosystem Exchange and biodiversity of forest ecosystems



# $O_3$ damage to crops and ecosystems




- a significant suppression of the global land-carbon sink as increases in ozone concentrations affect plant productivity
- Crop loss: 4% wheat in 2000 and 3% in Maize, well established for Europe an the US.
- In 2030 this will increase worldwide

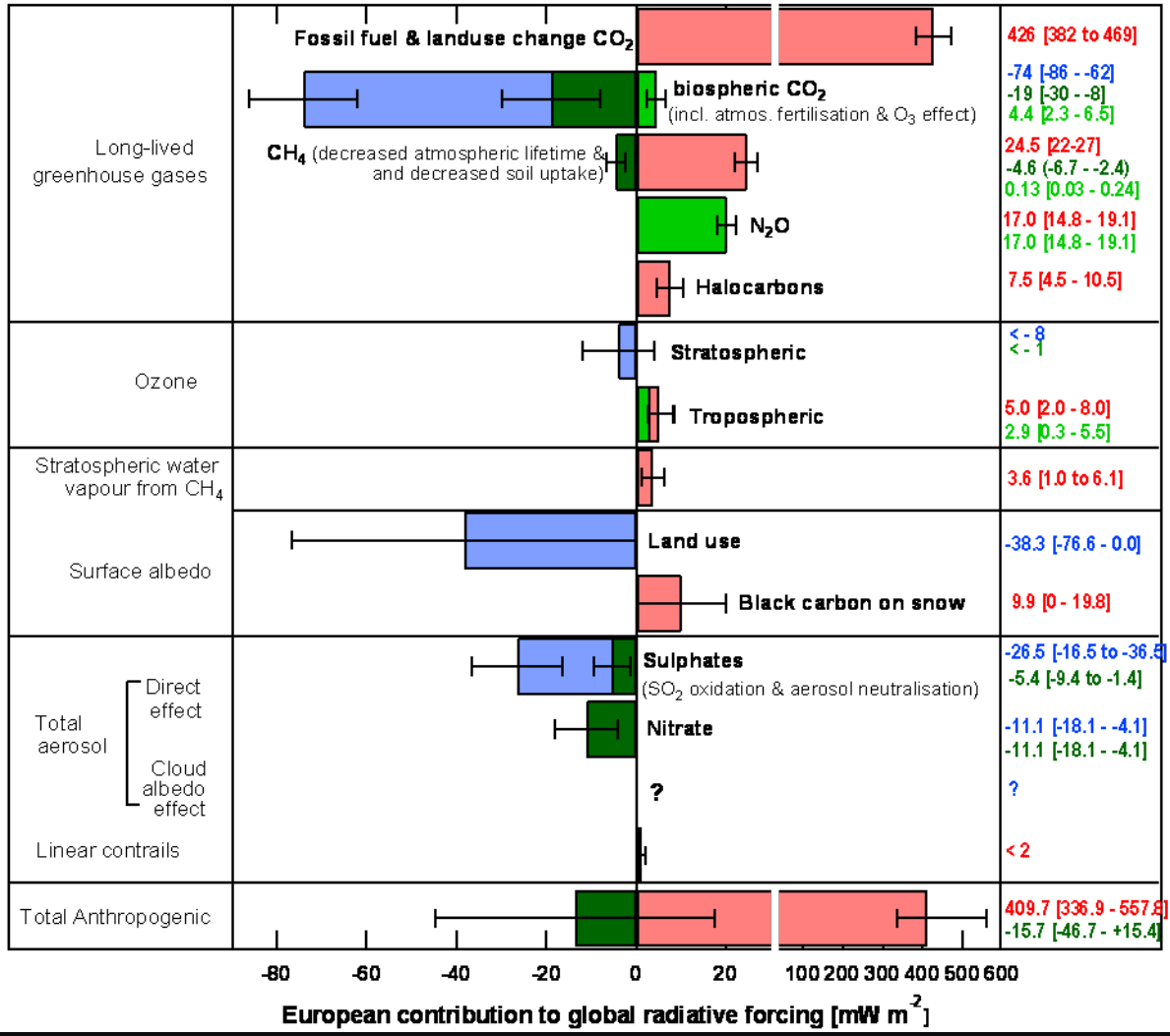
Ozone damage on brown knapweed and lettuce


Average relative yield loss from 2 metrics for the 4 crops, year 2000 (van Dingenen et al., 2008)

# Indirect effects of N on climate

- − Too little nitrogen can lead to decreased food production, soil erosion, and losses of carbon
- \+ Plants and soils sequester carbon. Nitrogen from fertilizer or atmospheric deposition can enhance C storage in forests and agricultural soils
- \+ Nitrogen fertilization of lakes, rivers, and estuaries increases productivity affecting C uptake.
- ± Nitrogen in deposition may currently be causing some C sequestration, particularly in forests, but full life-cycle analyses of the reactive N may show less of a net greenhouse gas benefit.
- − Excess N fertilization or deposition increases the loss of $CO_2$ to the atmosphere and $N_2O$ emission, and is having harmful effects on biodiversity, the quality of groundwater, rivers, lakes, and estuaries.

# Global radiative forcing due to European emissions




W/m$^2$

← -24

← +21

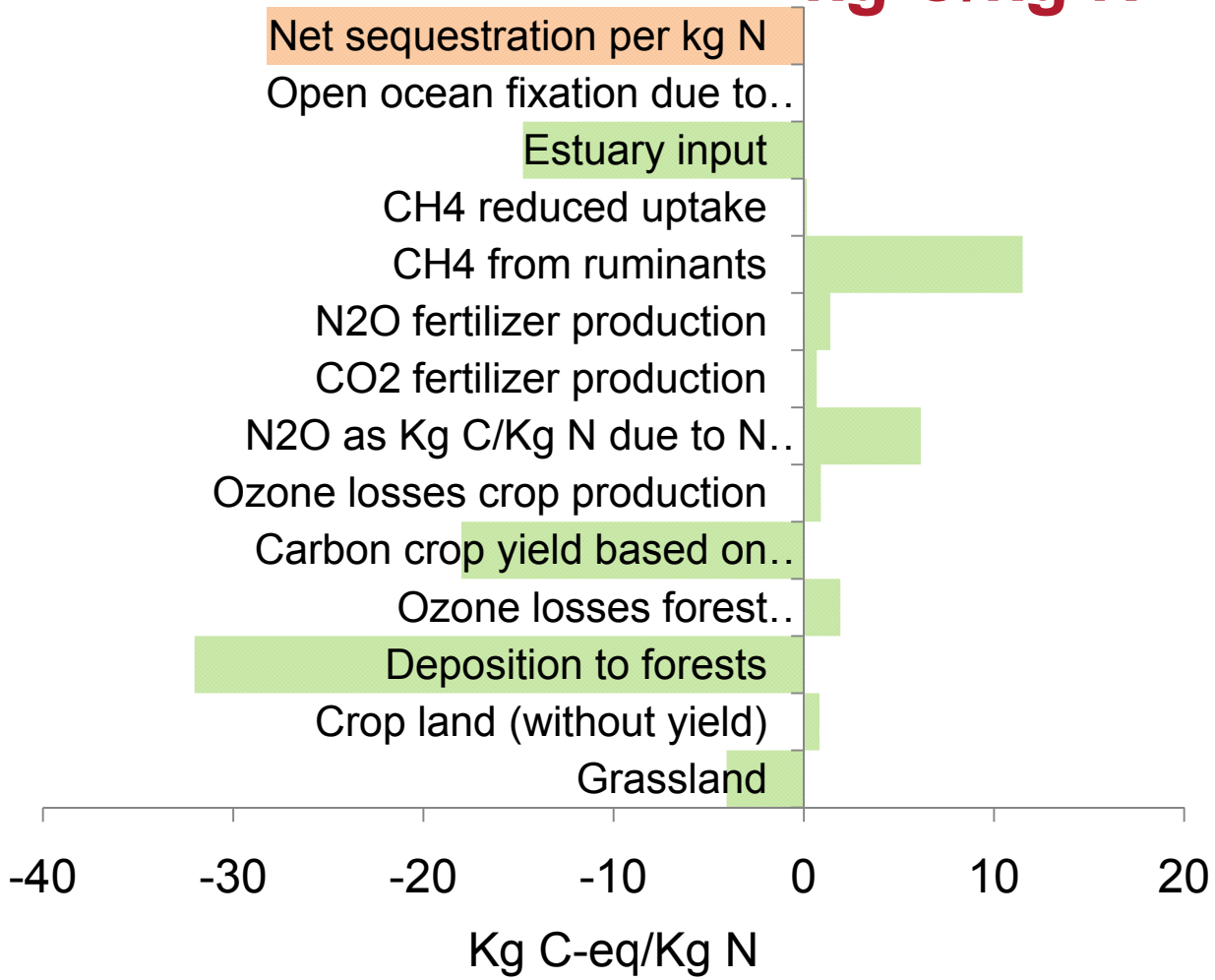
← +3

← -16

← -16

Butterbach-Bahl et al., 2011

# Net GHG effect in EU of 1 kg Nr in the cascade
## kg C/kg N

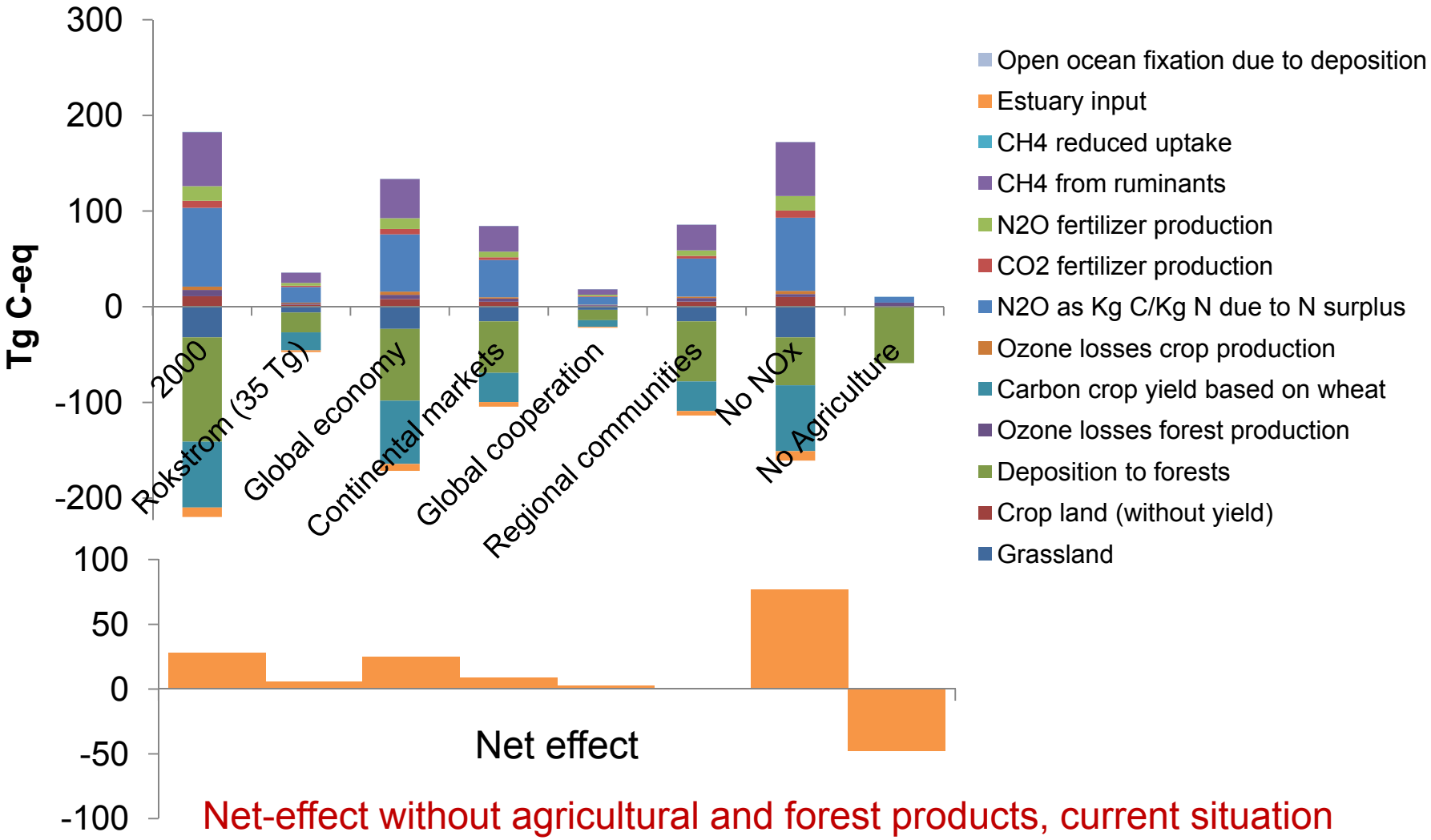



Sources:
- CarboEurope
- NitroEurope
- ACCENT
- Miterra
- EURURALIS

# EURURALIS scenario's


EURURALIS

# Scenario's of Nr production on the GHG balance (Eu)




Net-effect without agricultural and forest products, current situation

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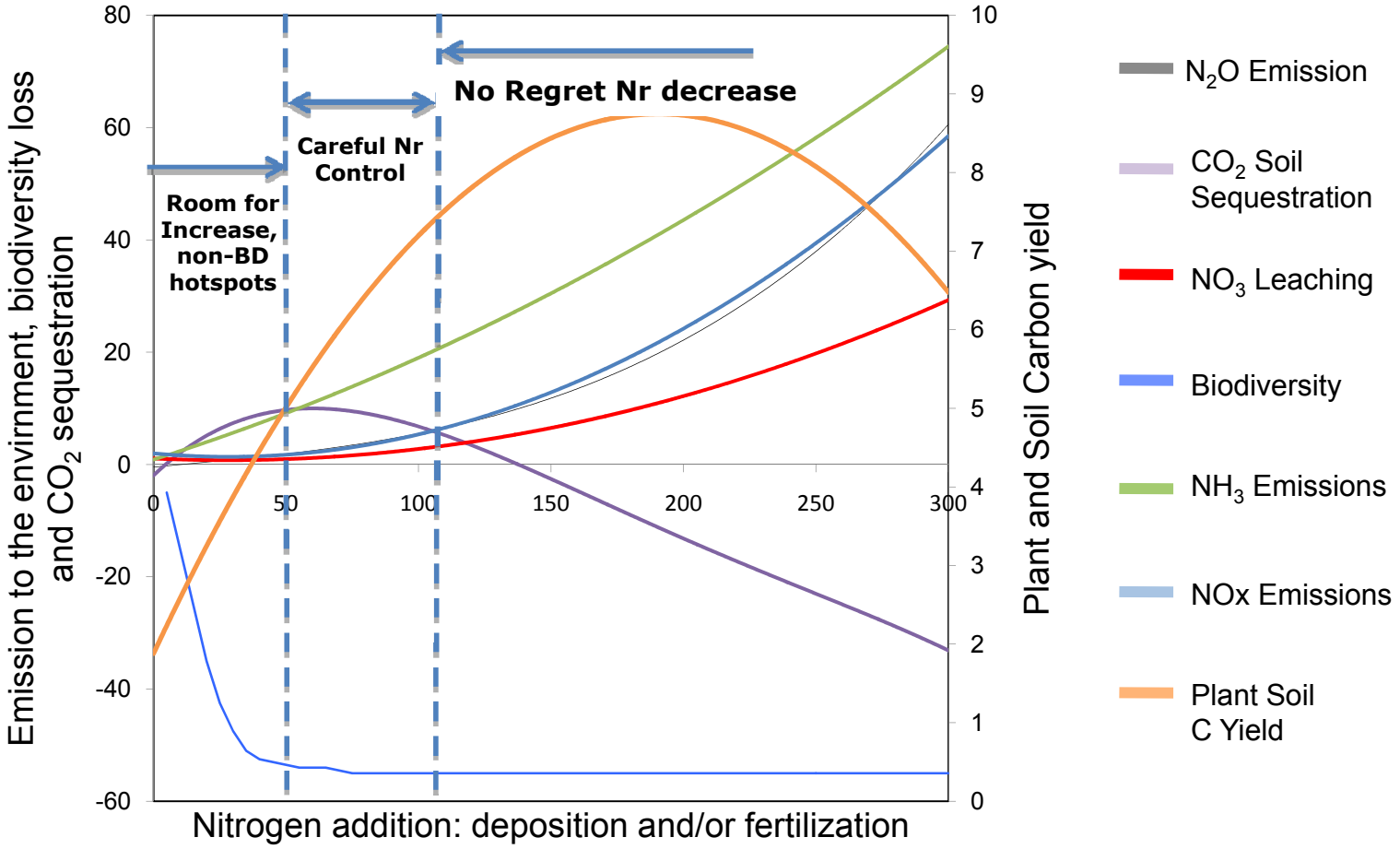
# Options for nitrogen management

# Three stages in the relationship between increasing Nr and response of climate relevant effects



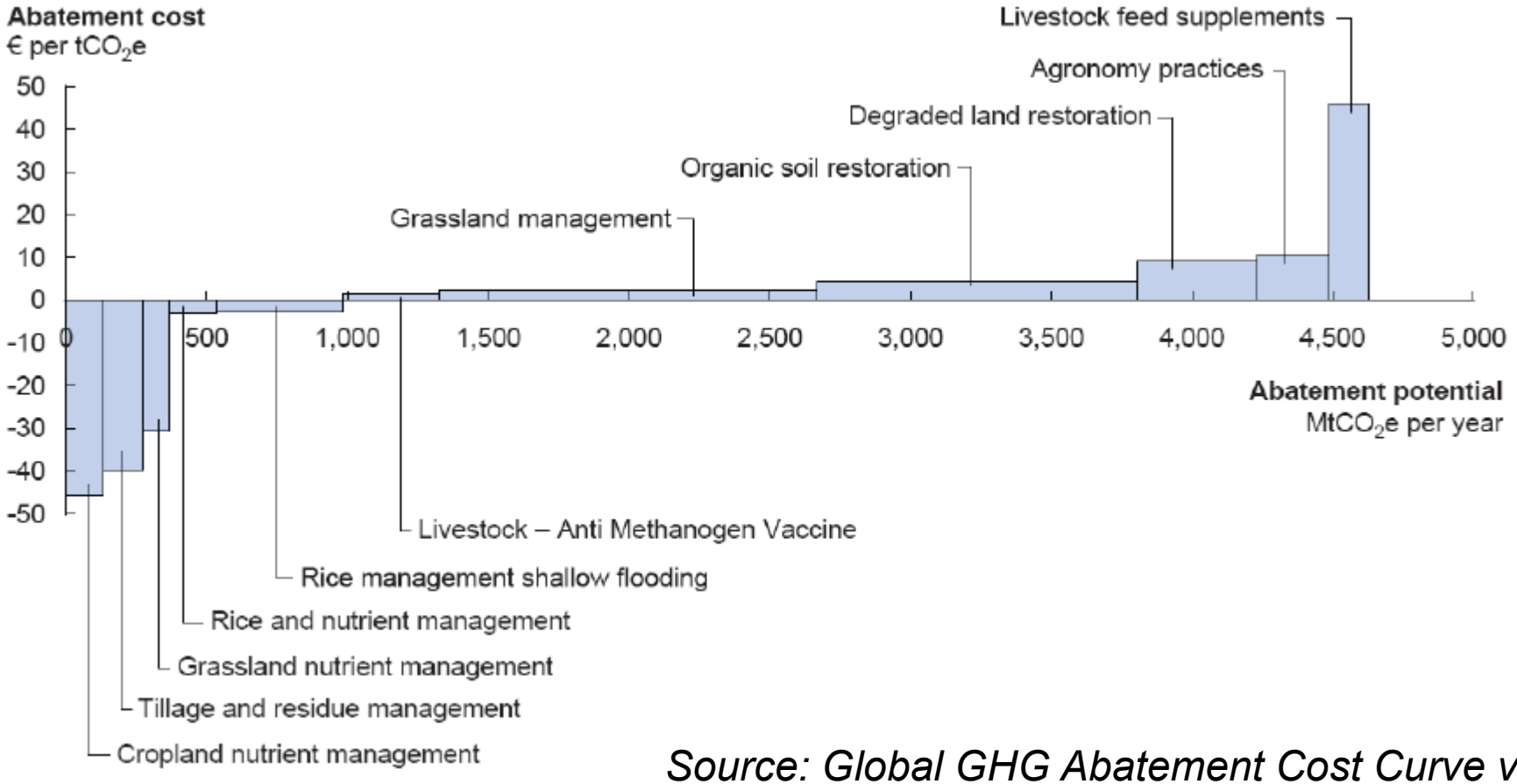

(Erisman et al., 2011)

# Cost effective GHG and N emission reduction in agriculture

- **Fertilizer production**
  - $N_2O$ abatement
  - Carbon sequestration
- **Fertilizer use**
  - Right time, place, technology, rate
  - Slow release fertilizers
- **Crop and land management**
  - Nitrogen and water management
  - Crop selection
  - Tillage
  - Optimize energy/food yields
- **Livestock:**
  - Increase productivity, manage manure and soil C
- **Product efficiency**
  - Bioenergy/food

Catalyst to reduce 95% $N_2O$ at fertilizer plants

# Global GHG abatement cost curve for the agriculture sector, 2030




*Source: Global GHG Abatement Cost Curve v2.0.*

# Solutions at Many Scales

- **Goal - optimize nitrogen's benefits - minimizing problems.**
  - Produce food with minimal Nr loss to environment
  - Produce energy with no Nr loss to environment
- **Action is possible at many levels**
  - Local--individuals can have impact.
  - National--need strategy and political will to manage N
  - International--N is global; integration among nations is critical.
- **Steps towards policies**
  - INI, serves as a forum for scientists, technologists and policy makers
  - Nanjing Declaration on Nitrogen Management (2004)
  - Global Partnership on Nutrient Management, GPNM (2007)
  - Task Force on Reactive Nitrogen, TFRN (2008)
- **To move the policy process forward**:
  - TFRN is drafting a report on Nitrogen and Climate
  - INI is convening a Global Nitrogen Assessment
  - IPCC will take N management into account in AR5 …..

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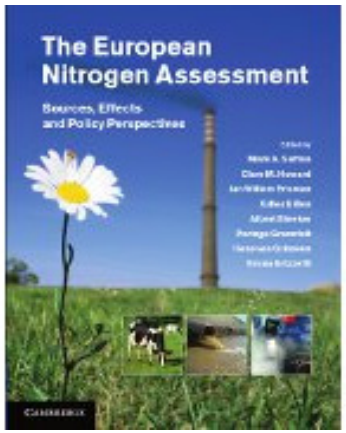
# Report on Nitrogen and Climate

www.ecn.nl

# Recognized by different organizations




- NitroEurope: Integrated project on Nr and GHG
- NinE: chapter in ENA
- TFRN: report to EB
- INI: Global Nitrogen Assessment
- IGBP: Synthesis&Integration
- GPNM: assessment of nutrients and climate effects in estuaries
- IPCC: AR5 in 2013

NitroEurope IP

NinE

ini

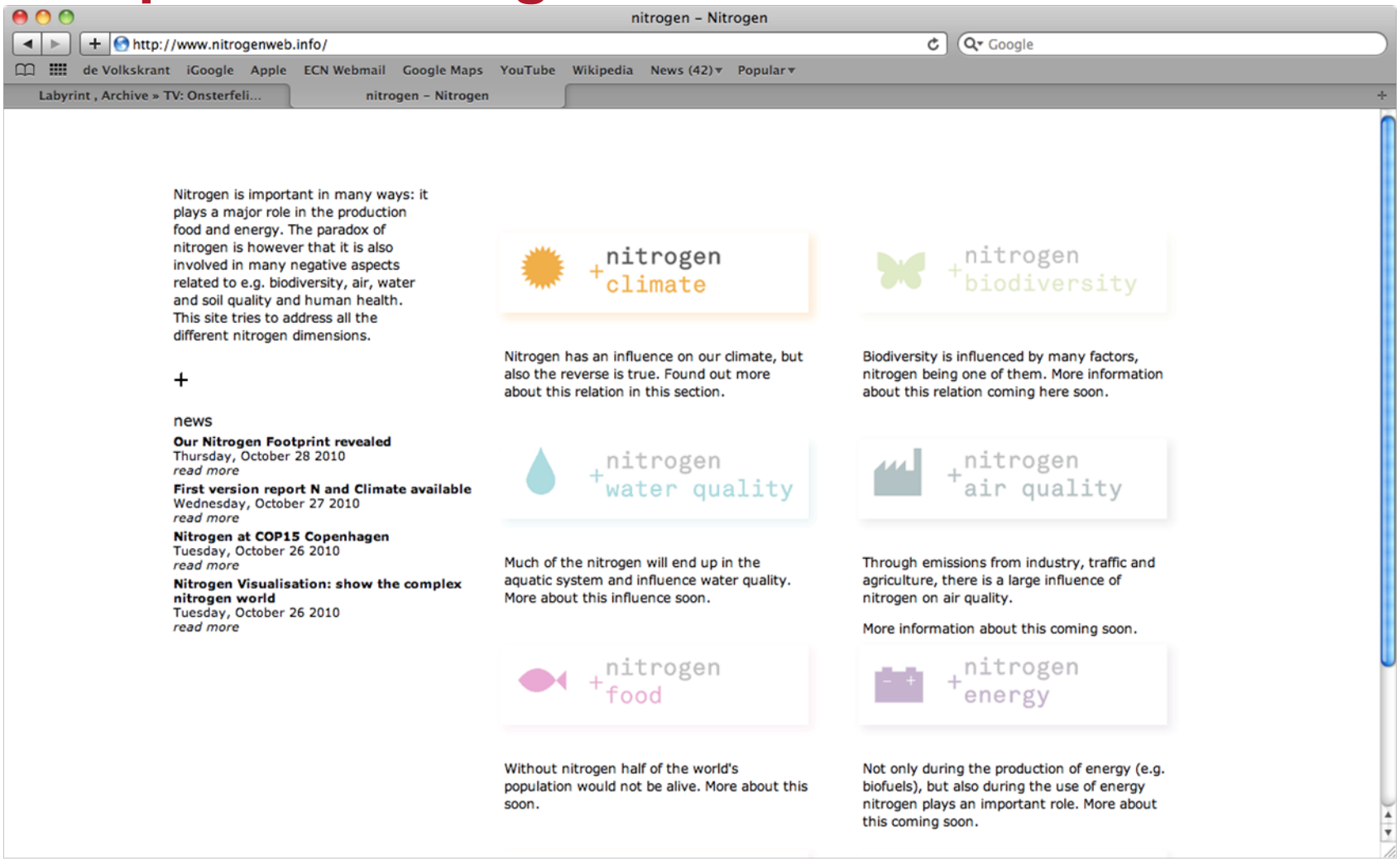
cost
Assessing and managing nitrogen fluxes in the atmosphere-biosphere system in Europe

GLOBAL CHANGE
IGBP
International Geosphere-Biosphere Programme

LRTAP
Long-range Transboundary Air Pollution

TFRN

# Report on Nitrogen and Climate - content



# Report on Nitrogen and Climate - procedure

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nitrogen + climate

This site is dedicated to the production of the Nitrogen+Climate Assessment Report, produced under the IGBP and TFRN.


partners

COST Action 729
Global Partnership on Nutrient Management
International Geosphere-Biosphere Programme (IGBP)
International Nitrogen Initiative
Nitrogen in Europe (NinE)
Task Force on Reactive Nitrogen (TFRN)
no title

This section of the website is called Nitrogen and Climate and was developed to support the Synthesis & Integration project under the International Geosphere - Biosphere Programme (IGBP) and the Task Force on Reactive Nitrogen (TFRN). This project develops an assessment report that looks into options for including nitrogen management in climate policy development, to be included in the IPCC process.

The timeline for the production and dissemination of this important Nitrogen + Climate assessment report is given below. The most recent *versions of the report* are also available. However, to get access to them you need to login. Please *contact us* for login details.

## Timeline

- Oct. 2010: Final draft report submitted to IPCC
- Oct. 2010: 32nd IPCC meeting: proposal for IPCC workshop in '11
- Dec. 2010: Final draft presented & discussed at *N2010*, India
- Dec. 2010: Ten pager summary submitted to the EB
- Apr. 2011: Final assessment report presented & launched at the Conference *Nitrogen and Global Change*
- Spring 2011: IPCC workshop on Nitrogen and Climate
- Summer 2011: High level publication based on report
- May 2012: Presented at Open Science conference Planet under Pressure, London.
- 2012: Presented at the Rio earth summit
- 2012: Royal Society meeting in the Global N cycle

## N+C News

Below you can find some news items directly linked to the N+Climate report. More general items can be found in the *News section*.

# Concluding remarks

- Fertilizing the biosphere with reactive nitrogen compounds lead to ecosystem, health, water and climate impacts
- Nitrogen deposition can lead to additional carbon sequestration and to impacts on biodiversity and ecosystem services
- Nitrogen addition to the biosphere might have a net cooling effect of 1 W/m$^2$; Life Cycle Analysis is needed to show the full impact
- Nitrogen management is essential for the environment and can have a positive effect on the net GHG exchange

# Acknowledgement

Gordon Bonan , Sybil Seitzinger, Owen Gaffney, Ninad Bondre., Bill Moomaw, Cliff Snyder, Albert Bleeker, Till Spranger, Maren Voss, Wim de Vries, Han Dolman, David Osborn, Chris Tompkins, Oene Oenema, Hans van Grinsven, Bob Howarth, Markku Kulmala, Veli-Matti Kerminen, Gilles Billen, Rik Leemans, Cheryl Palm, Jim Galloway, Eric Davidson, Alan Townsend, Klaus Butterbach-Bahl, Clare Britton, Mark Sutton, Wilfried Winiwarter, Ramesh Ramachandran, Remi Laane, Helmuth Thomas, Hartwig Kremer, Masumi Yamamuro, Peter Thornton, Whendee Silver, Jill Baron, Christine Goodale, Walt Reid, Zhang Fusuo, Frank Dentener, Rick Haeuber, Sarah Doherty, Paul Monks, Pete Smith, Mark Moore, Anni Reissell, Owen Gaffney, Ninad Bondre, Jean Paul Hettelingh, Mike Holland, Nancy Dise, Dennis Swaney, Johan Tidblad, Frank Dentener, Rik Leemans, Peter Vitousek, Anne Christine Le Gall and those I missed.

NitroEurope IP

NinE

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cost
Assessing and managing nitrogen fluxes in the atmosphere-biosphere system in Europe

GLOBAL CHANGE
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International Geosphere-Biosphere Programme

LRTAP
Long-range Transboundary Air Pollution

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