The use of nitrogen and biodiversity

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Biodiversity

- One of the most striking features of the Earth´s biota is its **extraordinary diversity**, estimated to include about **10 million different species.**

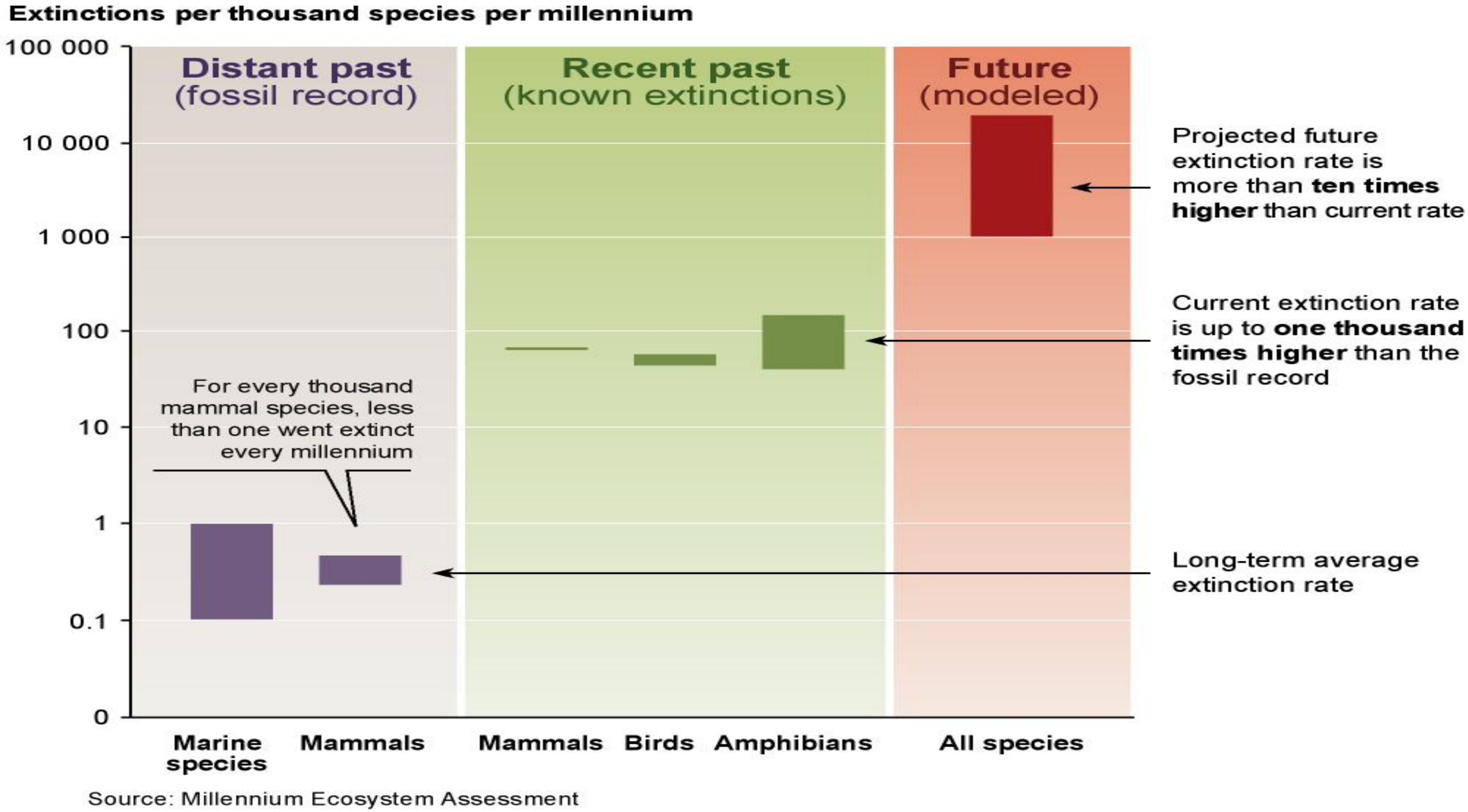
- **Biodiversity** is the total variety of life on Earth including all genes, species and ecosystems and the ecological processes of which the are part (CBD, 1992).

Biodiversity

- One of the most conspicuous aspects of contemporary global change is the **rapid decline of this diversity** in many ecosystems.

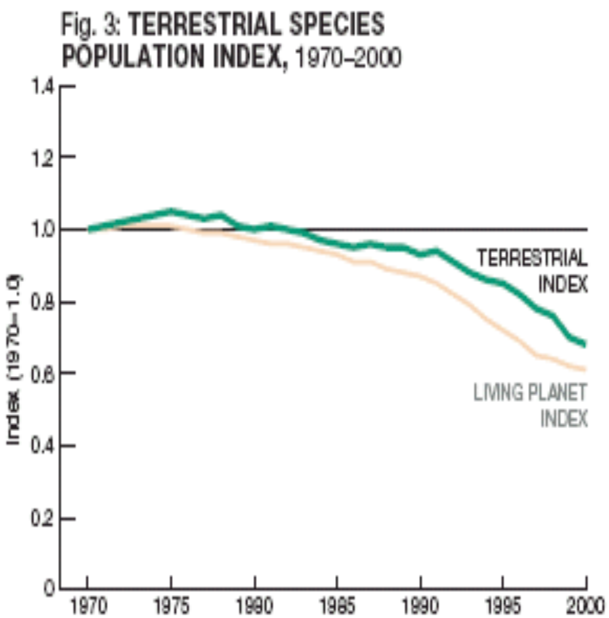
- The decline is not limited to increased rates of **species extinction**, but includes **losses in genetic and functional diversity** across population, community, ecosystem, landscape, and global scales.

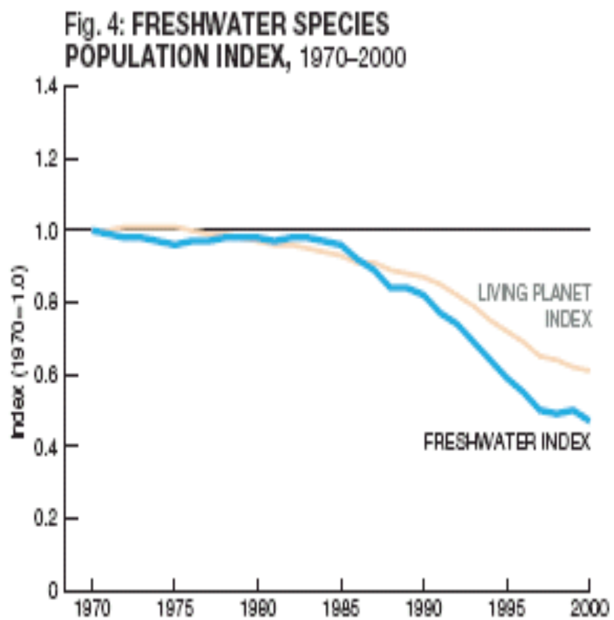
Species extinction

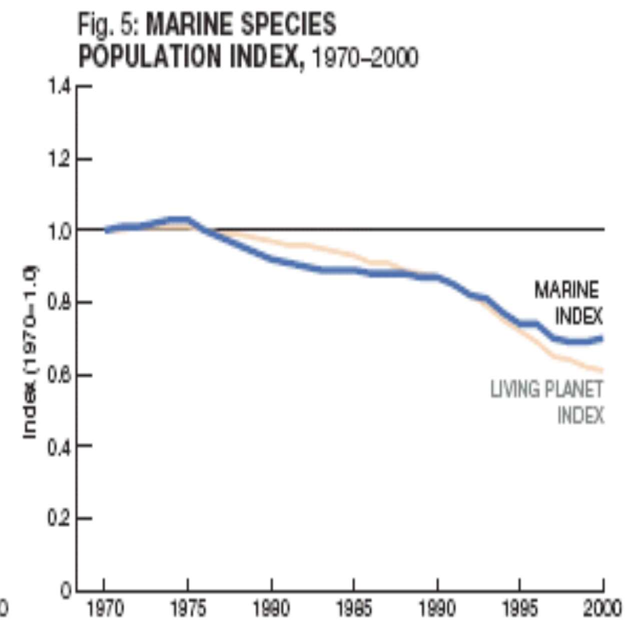


Current extinction rates are higher than geological rates

Biodiversity loss is accelerating…







From WWF, "Living Planet Report," 2004.

BBC NEWS

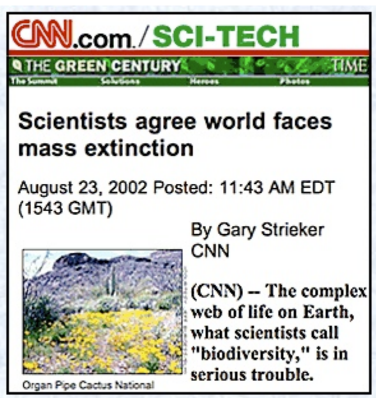
Tuesday, 21 May, 2002, 13:48 GMT 14:48 UK

Quarter of mammals 'face extinction'

Siberian tigers may vanish within three decades

By Corinne Podger
BBC science correspondent

Almost a quarter of the world's mammals face extinction within 30 years, according to a United Nations report on the state of the global environment.



CNN.com/SCI-TECH

THE GREEN CENTURY

Scientists agree world faces mass extinction

August 23, 2002 Posted: 11:43 AM EDT (1543 GMT)

By Gary Strieker
CNN

(CNN) -- The complex web of life on Earth, what scientists call "biodiversity," is in serious trouble.

Organ Pipe Cactus National

CNN.com/SCIENCE & SPACE

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AIRS: Saturdays 3 p.m. ET / Sundays 5 p.m. ET

Study: Only 10 percent of big ocean fish remain

By Marsha Walton
CNN
Wednesday, May 14, 2003 Posted: 10:29 PM EDT (0229 GMT)

(CNN) -- A new global study concludes that 90 percent of all large fishes have disappeared from the world's oceans in the past half century, the

BBC NEWS UK EDITION

Last Updated: Thursday, 18 September, 2003, 12:04 GMT 13:04 UK

Lions 'close to extinction'

Lion populations have fallen by almost 90% in the past 20 years, leaving the animal close to extinction in Africa, a wildlife expert has warned.

There are now only 23,000 left, compared to an estimated 200,000 two decades ago,

Live with them or lose them

SEE ALSO:
Wildlife watchers stay away from Kenya
22 Sep 98 | Africa
Kenyan lions killed in revenge attacks
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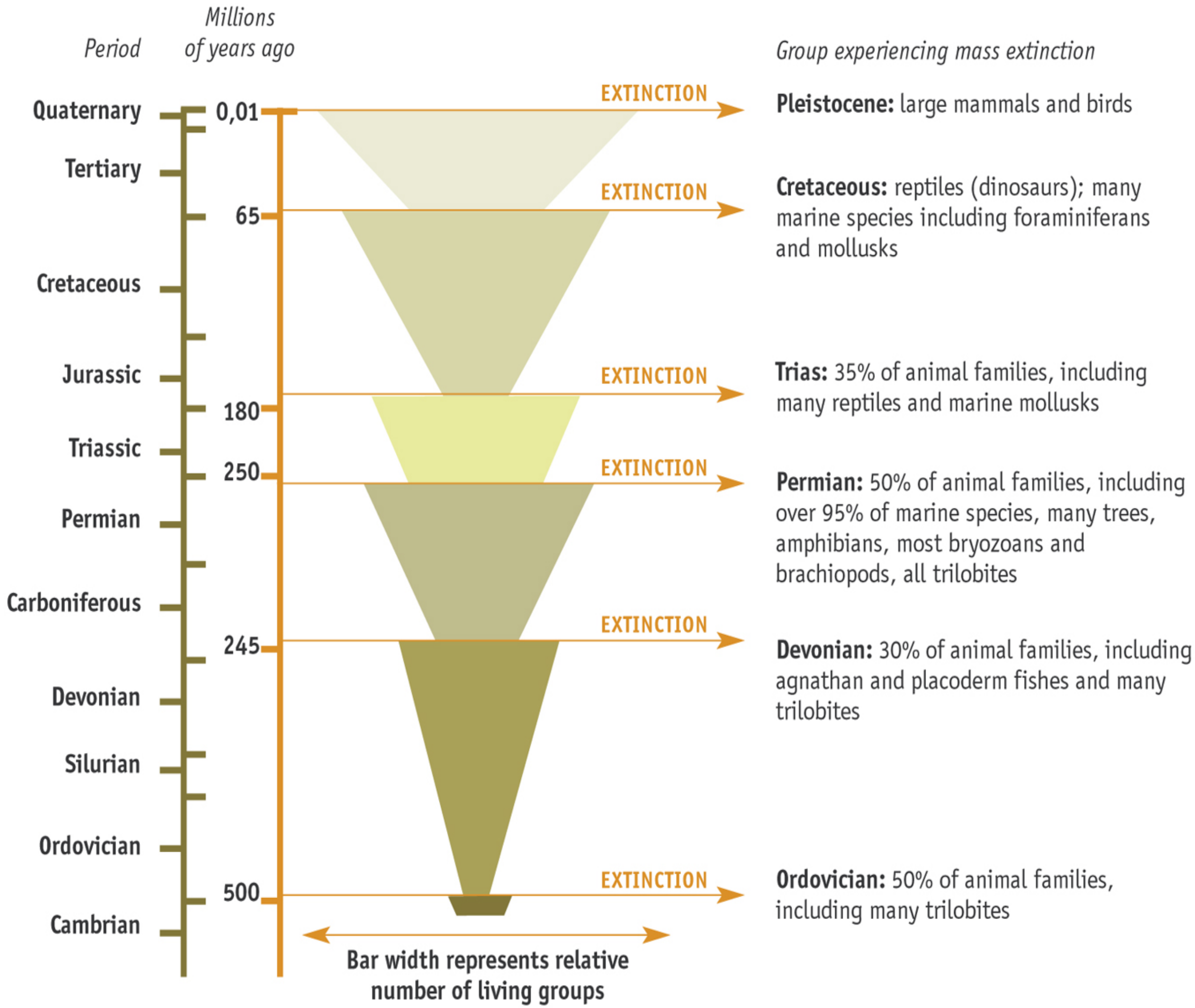
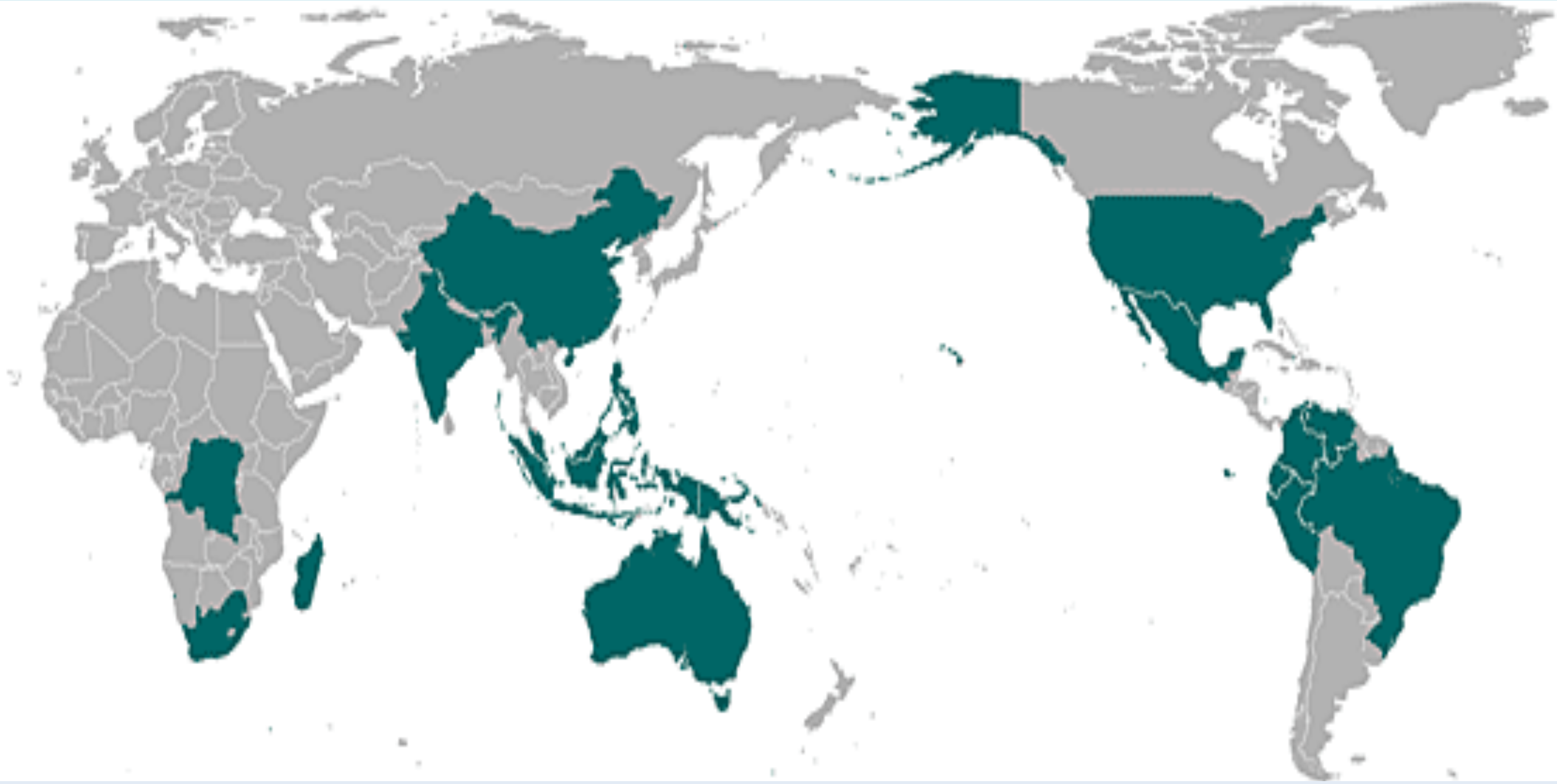
The sixth wave of extinctions in the past half-billion years



Megadiverse countries



- **17 countries which have been identified as the most biodiversity-rich** countries of the world, with a particular focus on **endemic biodiversity**.
- Many of them are located in, or partially in, **tropical or subtropical regions**.

Loss of biodiversity

- The wide-ranging decline in biodiversity results largely from
  - habitat modifications and destruction,
  - increased rates of invasions by deliberately or accidentally introduced non-native species,
  - over-exploitation
  - other human-caused impacts.

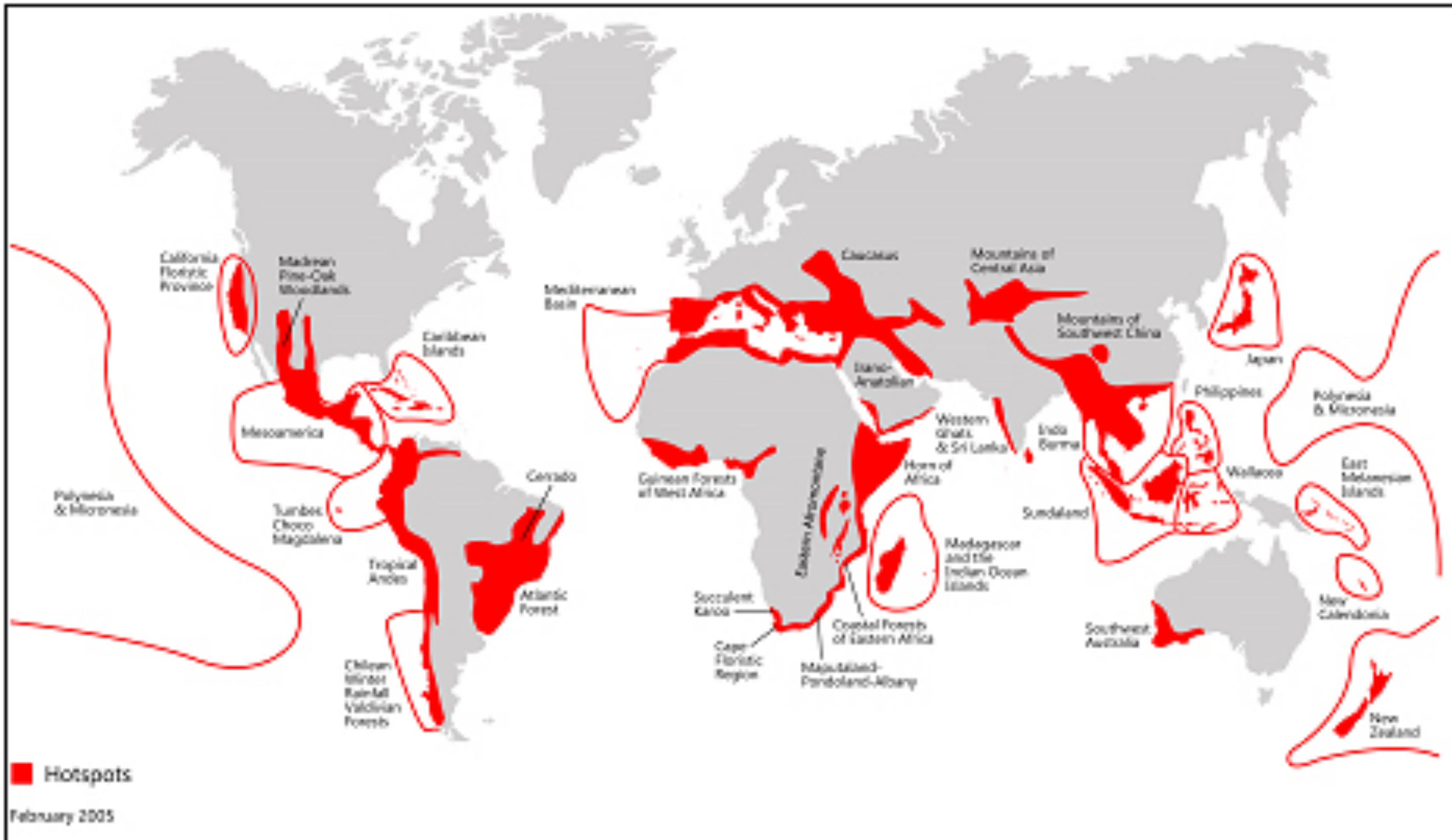
Biodiversity Hotspots

- There are places on Earth that are both biologically rich — and deeply threatened.
- Around the world, 35 areas qualify as hotspots.
- They represent just 2.3% of Earth's land surface, but they support
  - more than 50% of the world's plant species as endemics
  - nearly 43% of bird, mammal, reptile and amphibian species as endemics.

Source: http://www.conservation.org

Biodiversity Hotspots

CONSERVATION INTERNATIONAL



Biodiversity Hotspots

- The map of hotspots overlaps with the map of the natural places that most benefit people.
- Hotspots are among the richest and most important ecosystems in the world
- Home to many vulnerable populations who are directly dependent on nature to survive.
- **Despite comprising 2.3% of Earth's land surface, hotspots account for 35% of the "ecosystem services" that vulnerable human populations depend on.**

Source: http://www.conservation.org

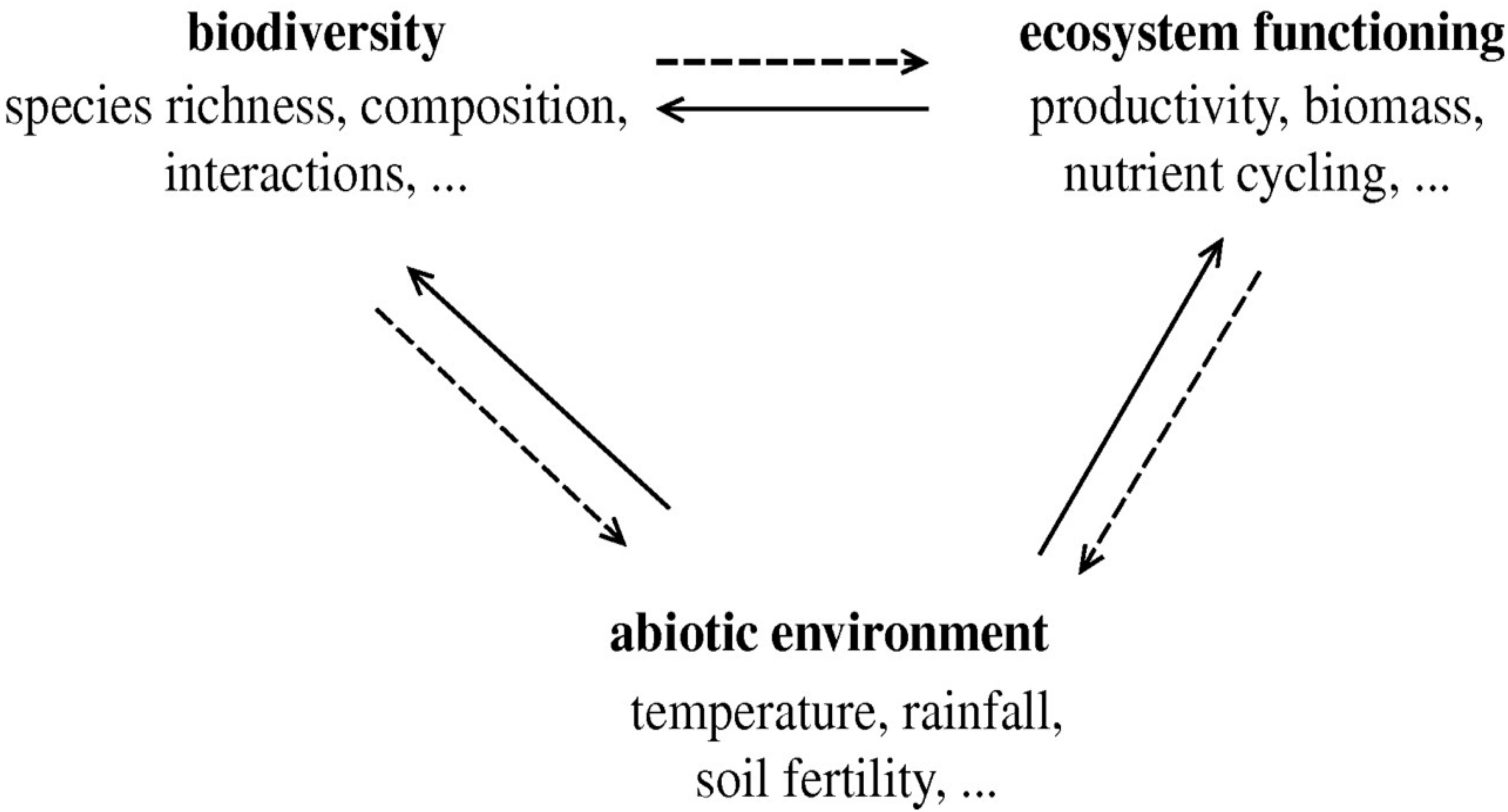
Biodiversity and Ecosystem Functioning

- **Species diversity is a major determinant** of ecosystem productivity, stability, invasibility, and nutrient dynamics.
- Hundreds of studies spanning terrestrial, aquatic, and marine ecosystems show
- **high-diversity mixtures are approximately twice as productive as monocultures** of the same species and that this difference increases through time.

Tilman, Isbell, and Cowles Annual Review of Ecology, Evolution, and Systematics, Vol. 45: 471-493, 2014.

Biodiversity and Ecosystem functions

- **Critical processes at the ecosystem level** influence
  - plant productivity, soil fertility, water quality, atmospheric chemistry, and many other local and global environmental conditions that ultimately affect human welfare.
- These ecosystem processes are **controlled by both the diversity and identity of the plant, animal, and microbial species** living within a community.



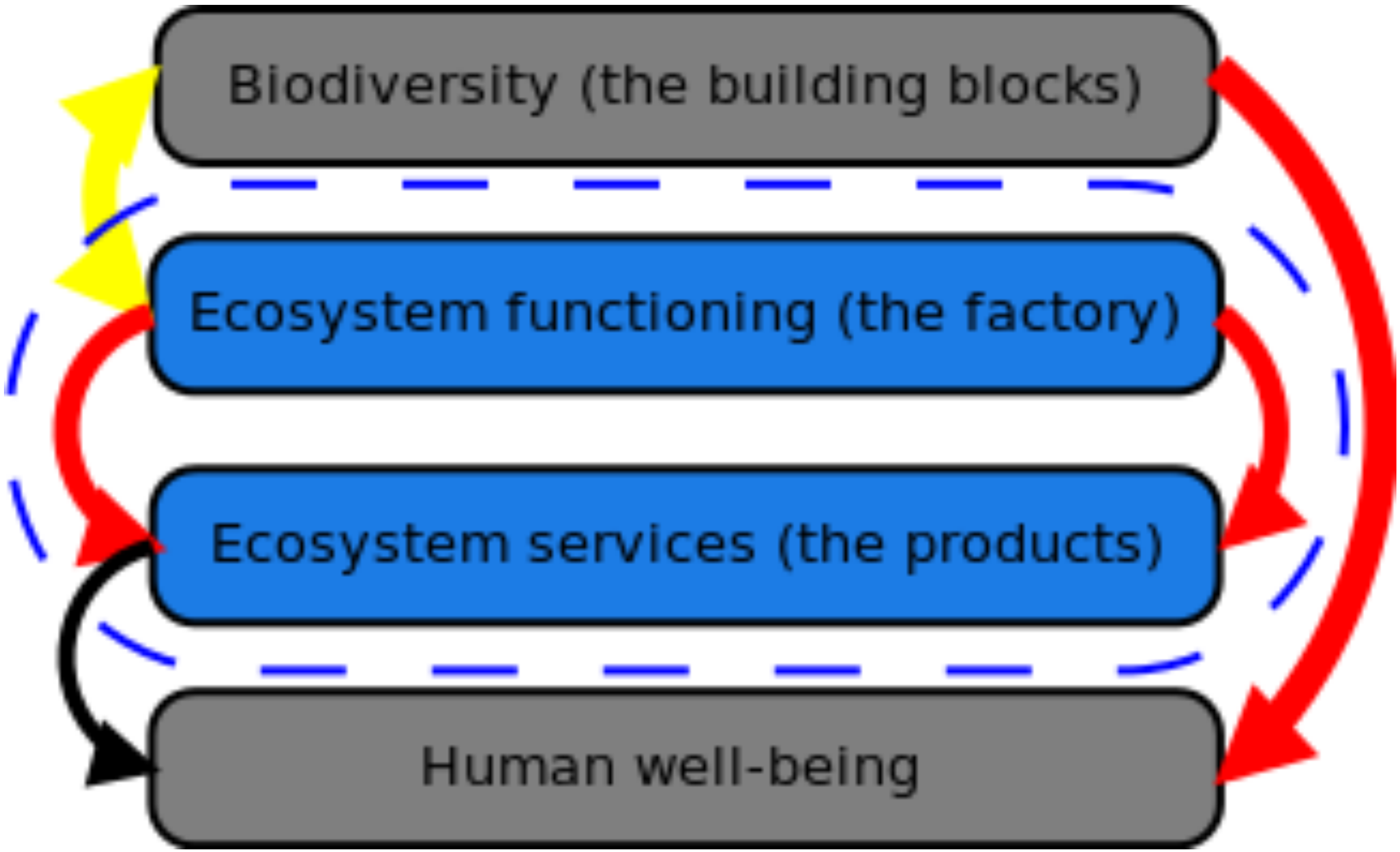
biodiversity
species richness, composition,
interactions, ...
ecosystem functioning
productivity, biomass,
nutrient cycling, ...
abiotic environment
temperature, rainfall,
soil fertility, ...

Biodiversity and Ecosystem functions

- The primary cause has been widespread human transformation of **once highly diverse natural ecosystems into relatively species-poor managed ecosystems.**

- **Reductions in biodiversity can alter both the magnitude and the stability of ecosystem processes**.

- Changes in ecological functions and life support services that are vital to the **well-being of human societies.**


Biodiversity (the building blocks)
Ecosystem functioning (the factory)
Ecosystem services (the products)
Human well-being

Effects of diversity on Ecosystem Processes

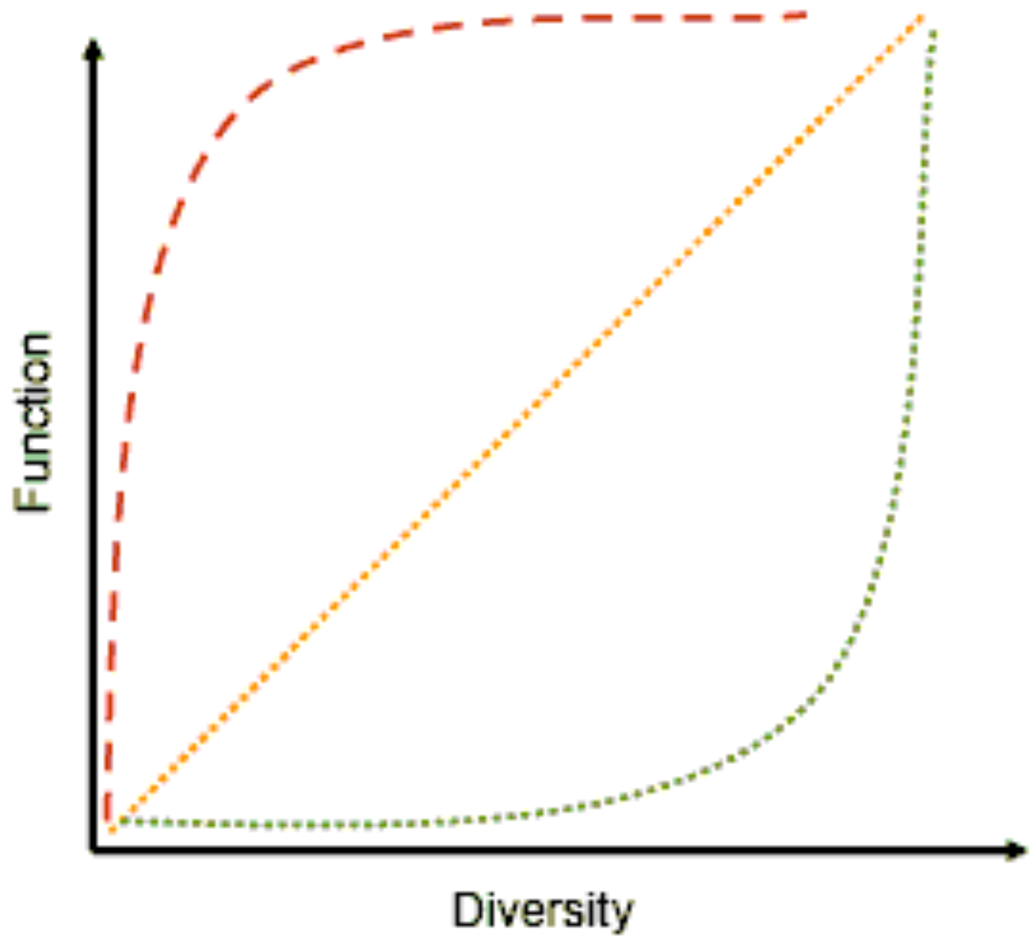
- The number, relative abundance, identity and interactions between species affect ecosystem processes

- The functional consequences of changes in diversity depend on:
  - Species richness (number of species)
  - Equitability (their relative abundances)
  - Species composition (identity of the species present)
  - Interactions between species
  - Temporal and spatial variation of these properties

- Each of these components affects the diversity of ecosystem functioning

Relationship Diversity x Function

I. Every species contributes a new function
II. Many species functionally important
III. Few species functionally singular



Biodiversity and Ecosystem Functioning

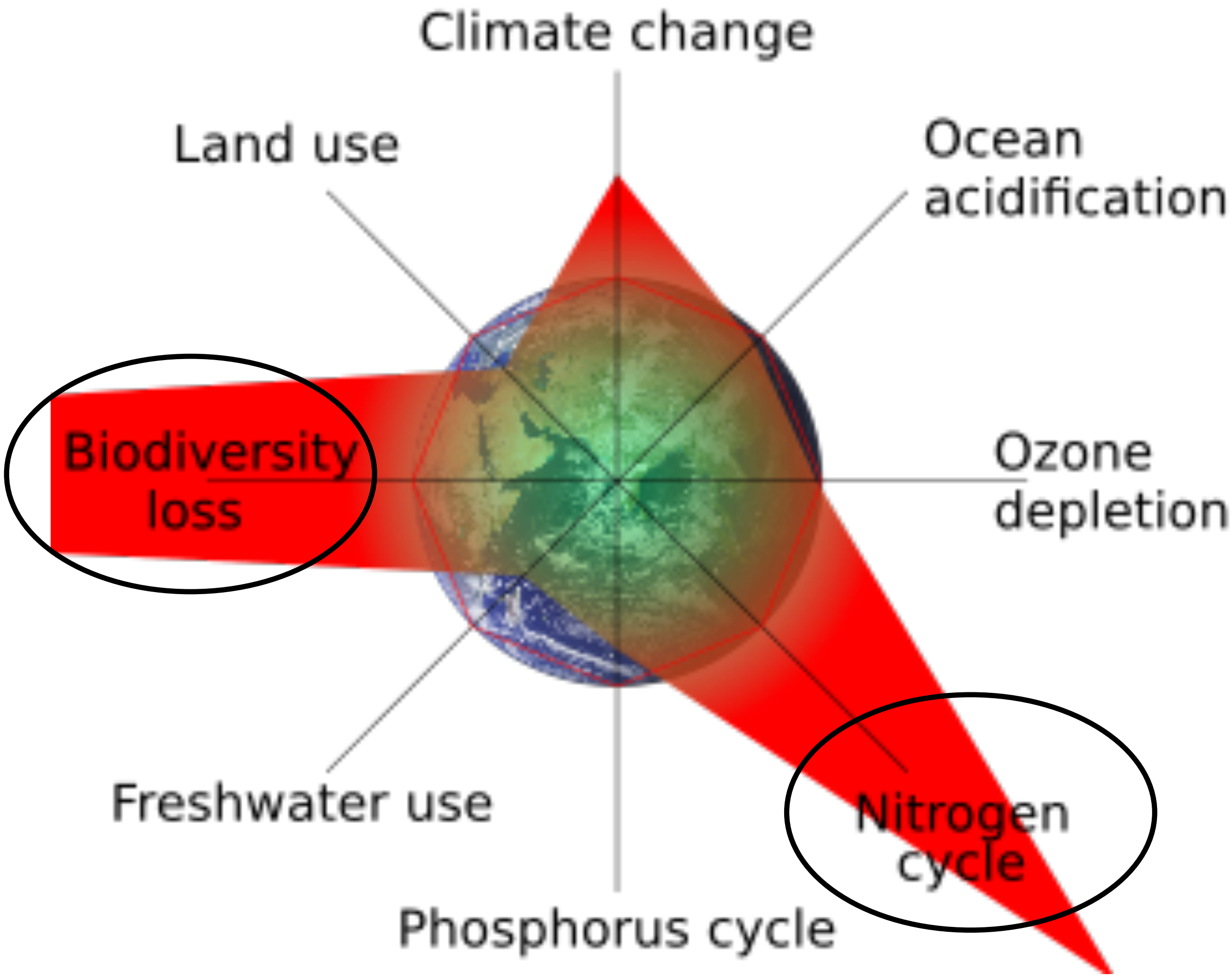
- Higher diversity effects on ecosystems have multiple causes, including:
  - interspecific complementarity,
  - greater use of limiting resources,
  - decreased herbivory and disease,
  - and nutrient-cycling feedbacks that increase nutrient stores and supply rates over the long term.

Biodiversity and Ecosystem Functioning

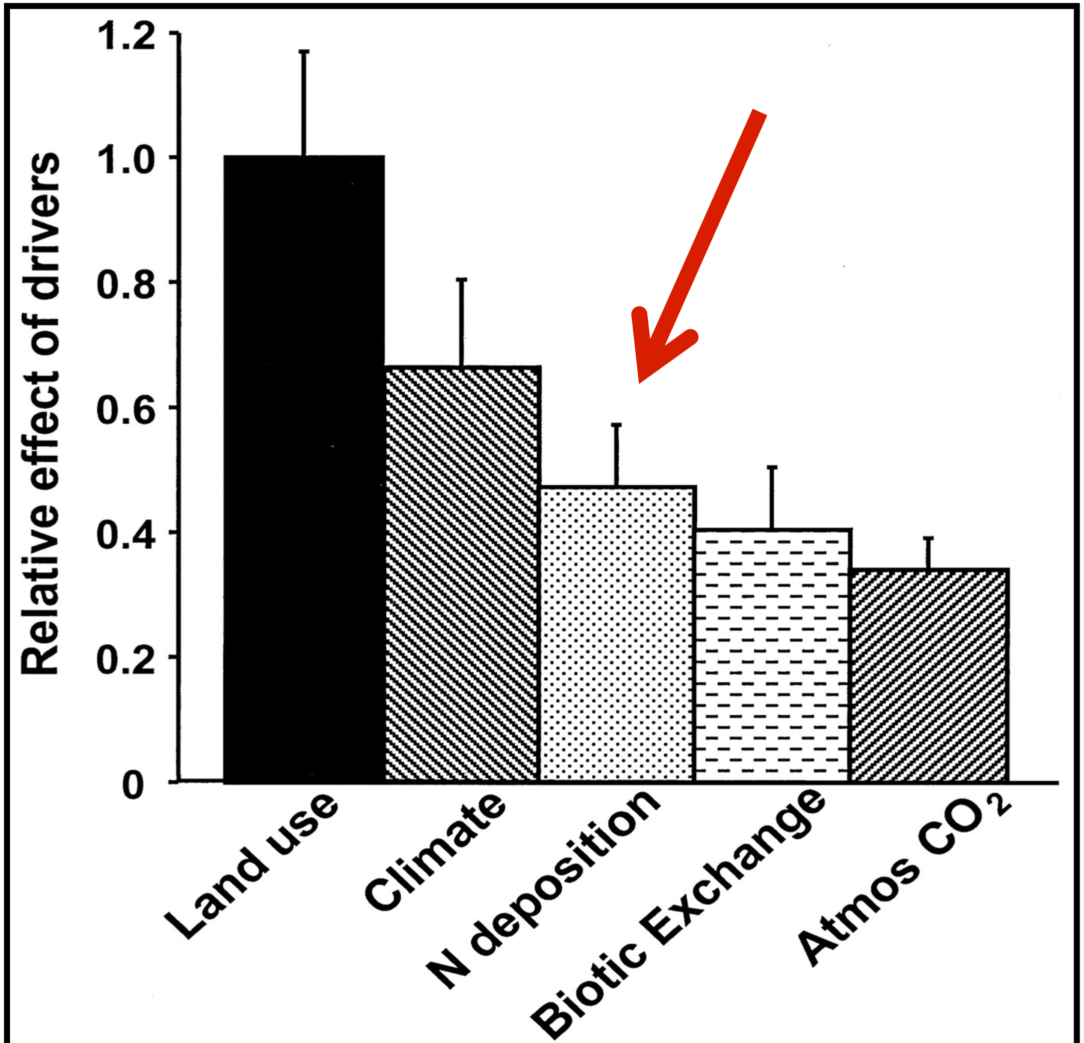
- Diversity loss has an effect as great as, or greater that, the effects of:
  - herbivory, fire, drought, nitrogen addition, elevated CO2, and other drivers of environmental change.

The preservation, conservation, and restoration of biodiversity should be a high global priority.

Planetary boundaries



Global environmental changes and Biodiversity – Scenarios 2100



Sala et al. 2000
Science 287:1770-1774

- **Convention on Biological Diversity Aichi Targets 2010**

- Target 8: “By 2020, pollution, including from **excess nutrients**, has been brought to levels that are not detrimental to ecosystem function and biodiversity.”

- **Key focus on nitrogen**. Each country free to set its own indicators and goals.

Changes in global N cycle

- **Nitrogen**
  - key element for life on Earth
  - related to ecosystem functioning and many human activities
  - under strong pressure due to current global environmental changes.

Nitrogen

- Nitrogen is a very dynamic element.
- It not only exists on Earth in many forms, but also undergoes many transformations in and out of the soil.
- The sum of these transformations is known as the **nitrogen cycle**.

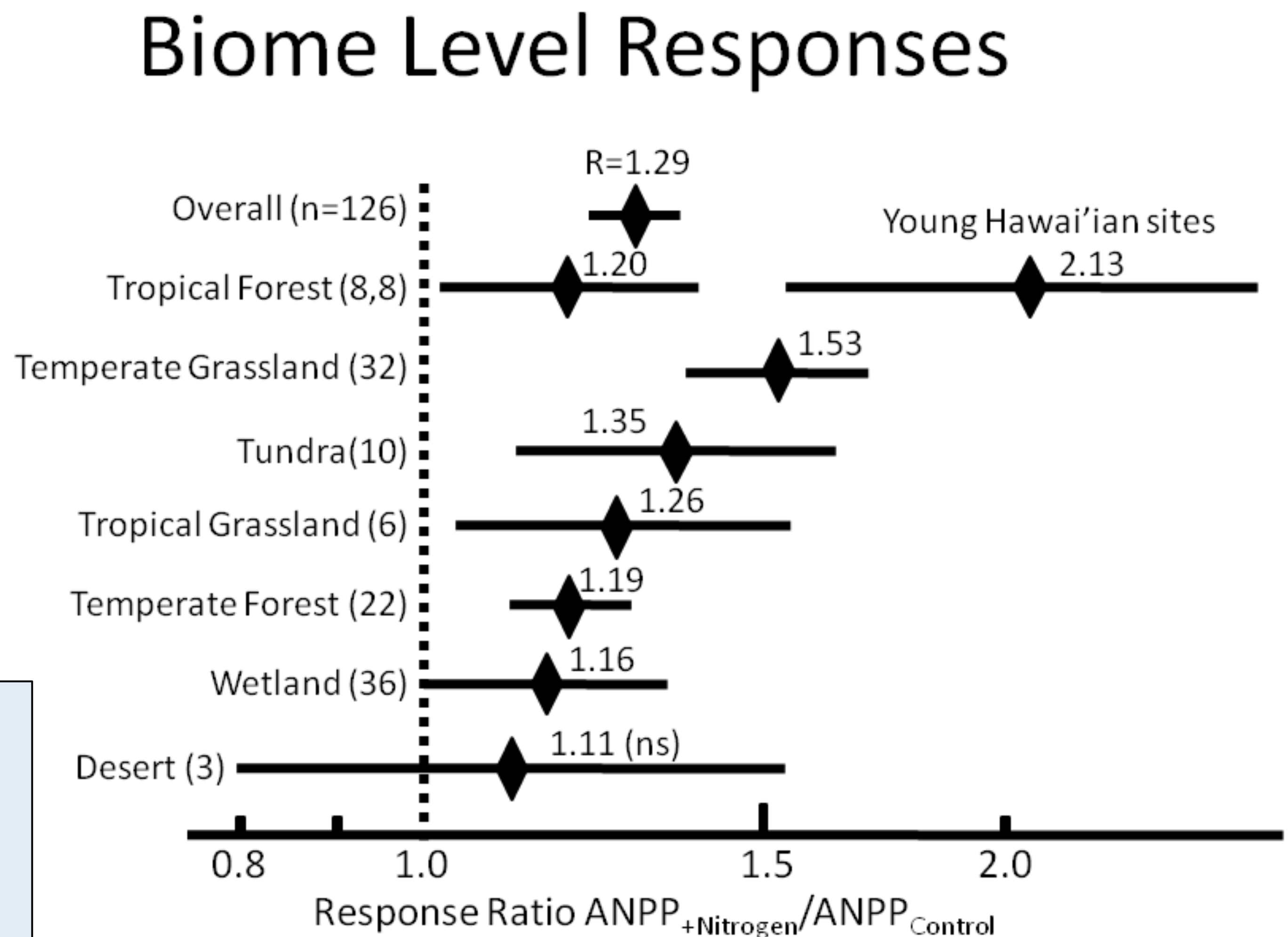
Nitrogen

- Of all the essential nutrients, **nitrogen is required by plants in the largest quantity and is most frequently the limiting factor** in crop productivity.
- In plant tissue, the nitrogen content ranges from 1 and 6%.

Primary productivity x N addition

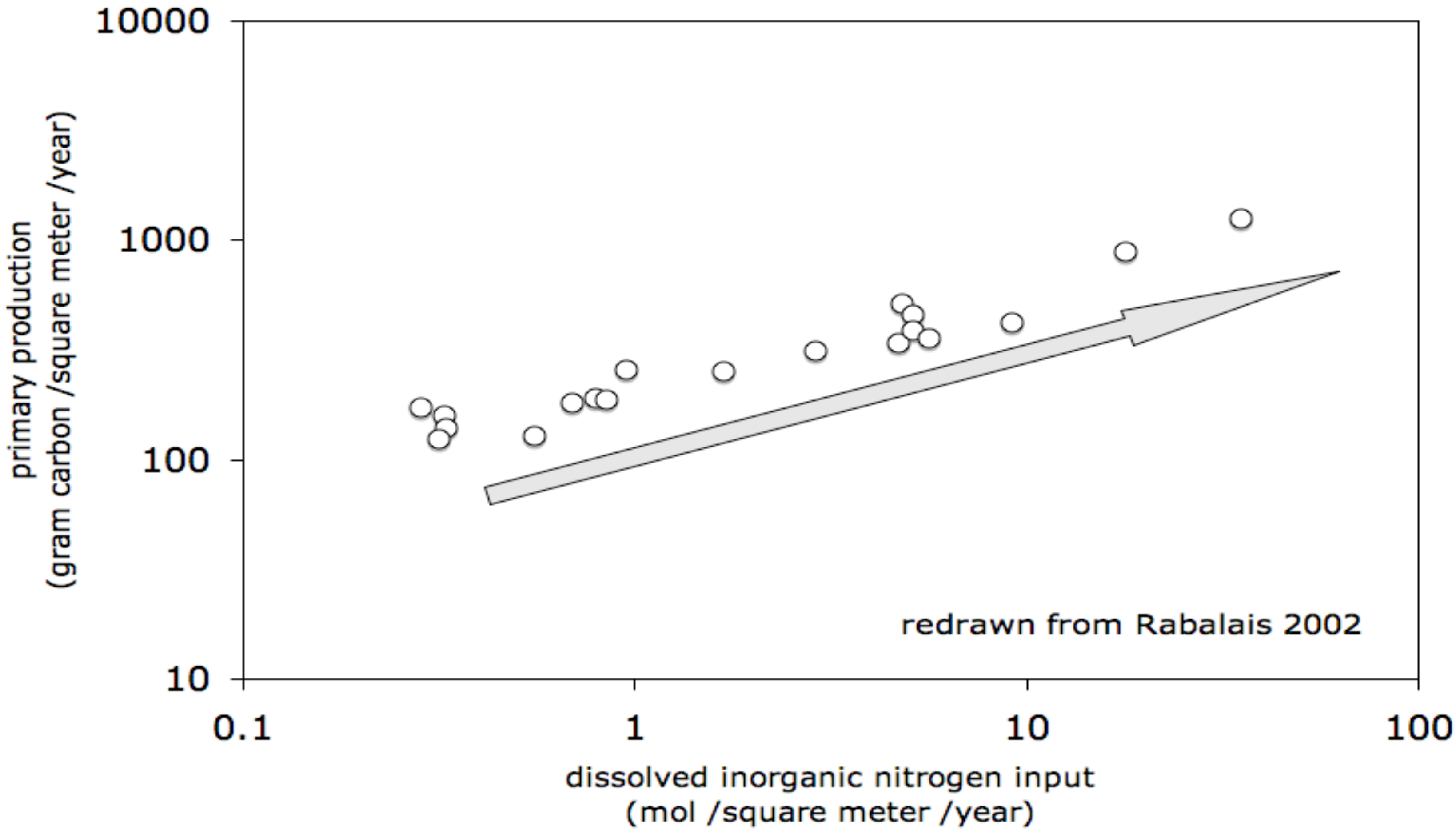
Response ratios for overall mean and individual biomes exposed to nitrogen fertilizer.

A response ratio of 1.2 indicates a 20% relative growth increase (mean and 95% C.I.)

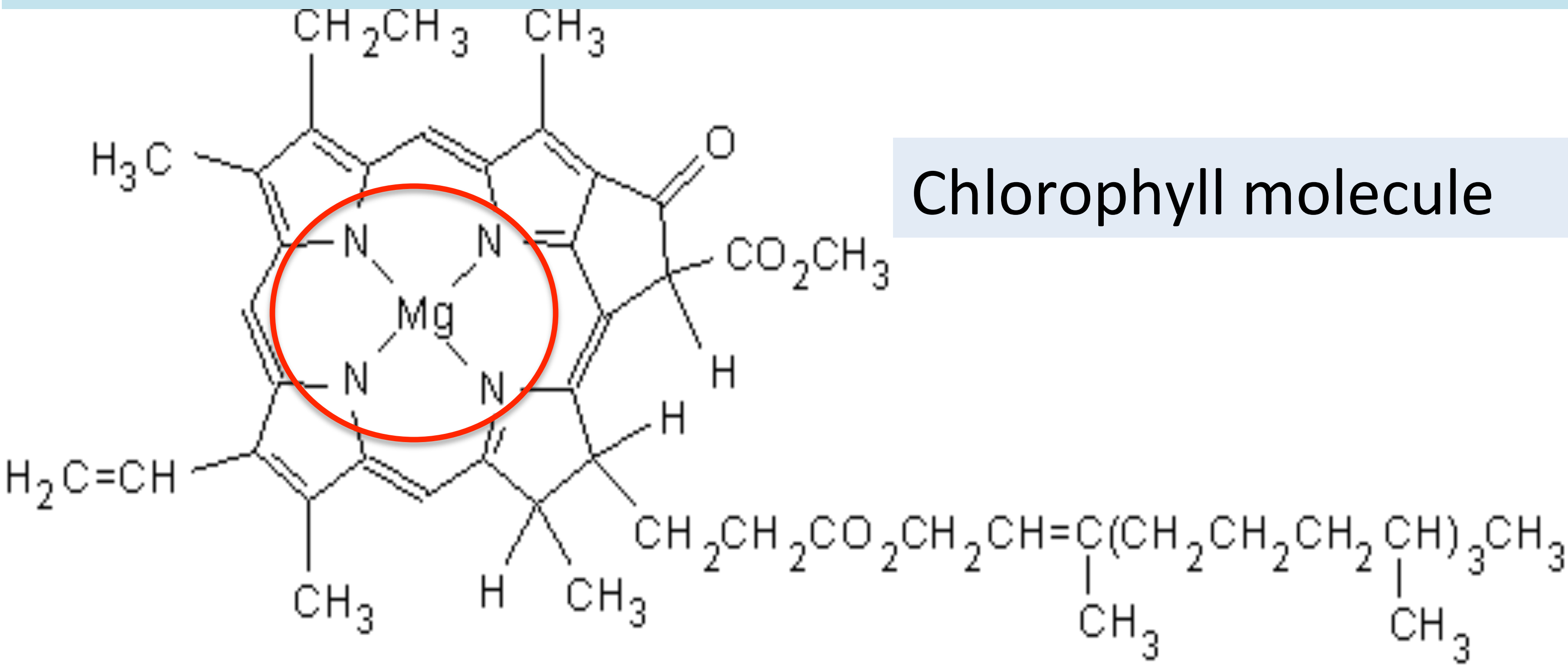


LeBauer, David and Kathleen K. Treseder. "Nitrogen limitation of net primary productivity in terrestrial ecosystems is globally distributed", Ecology 89, 2008

Input of N x primary production



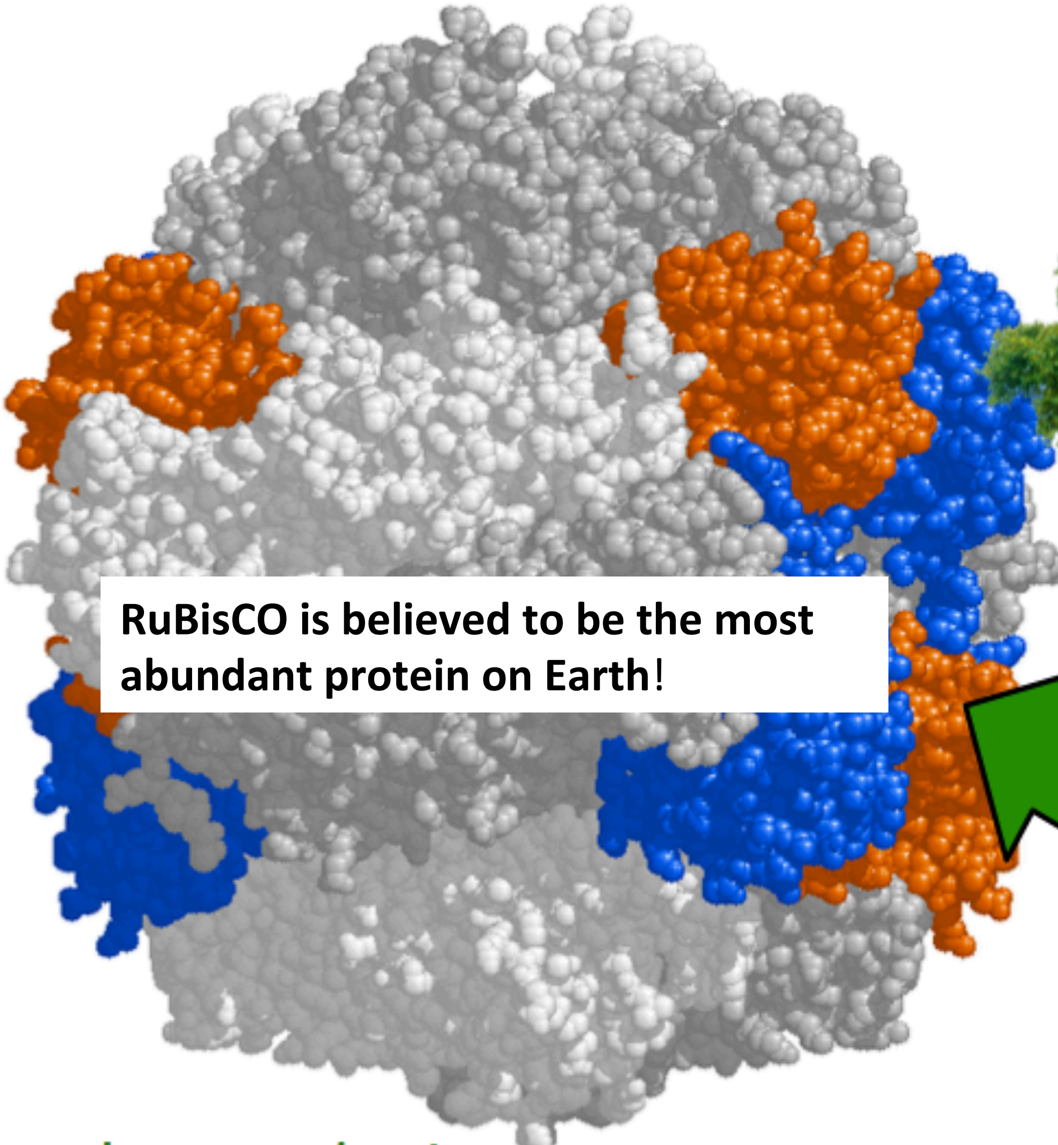
Nitrogen and photosynthesis



Chlorophyll molecule

Nitrogen in chlorophylls, thylakoid proteins, and associated cofactors and enzymes (particularly rubisco, which may account for 20–40% of a leaf's organic N) comprises about 75% of a leaf's organic N.

Ribulose-1,5-bisphosphate carboxylase oxygenase



RuBisCO is believed to be the most abundant protein on Earth!

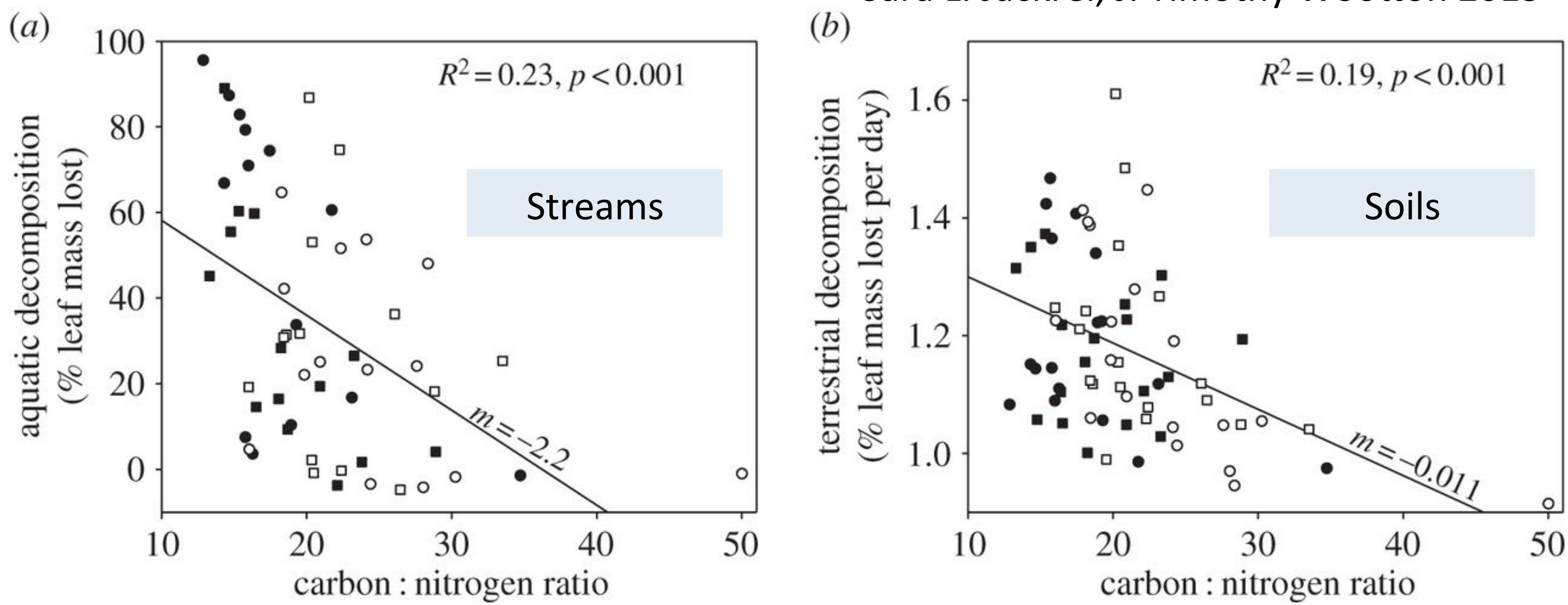
Carbon fixation done by the enzyme RuBisCO

photosynthesis:

$$2n\ CO_2 + 4n\ H_2O \xrightarrow{\text{light}} 2(CH_2O)_n + 2n\ O_2 + 2n\ H_2O$$

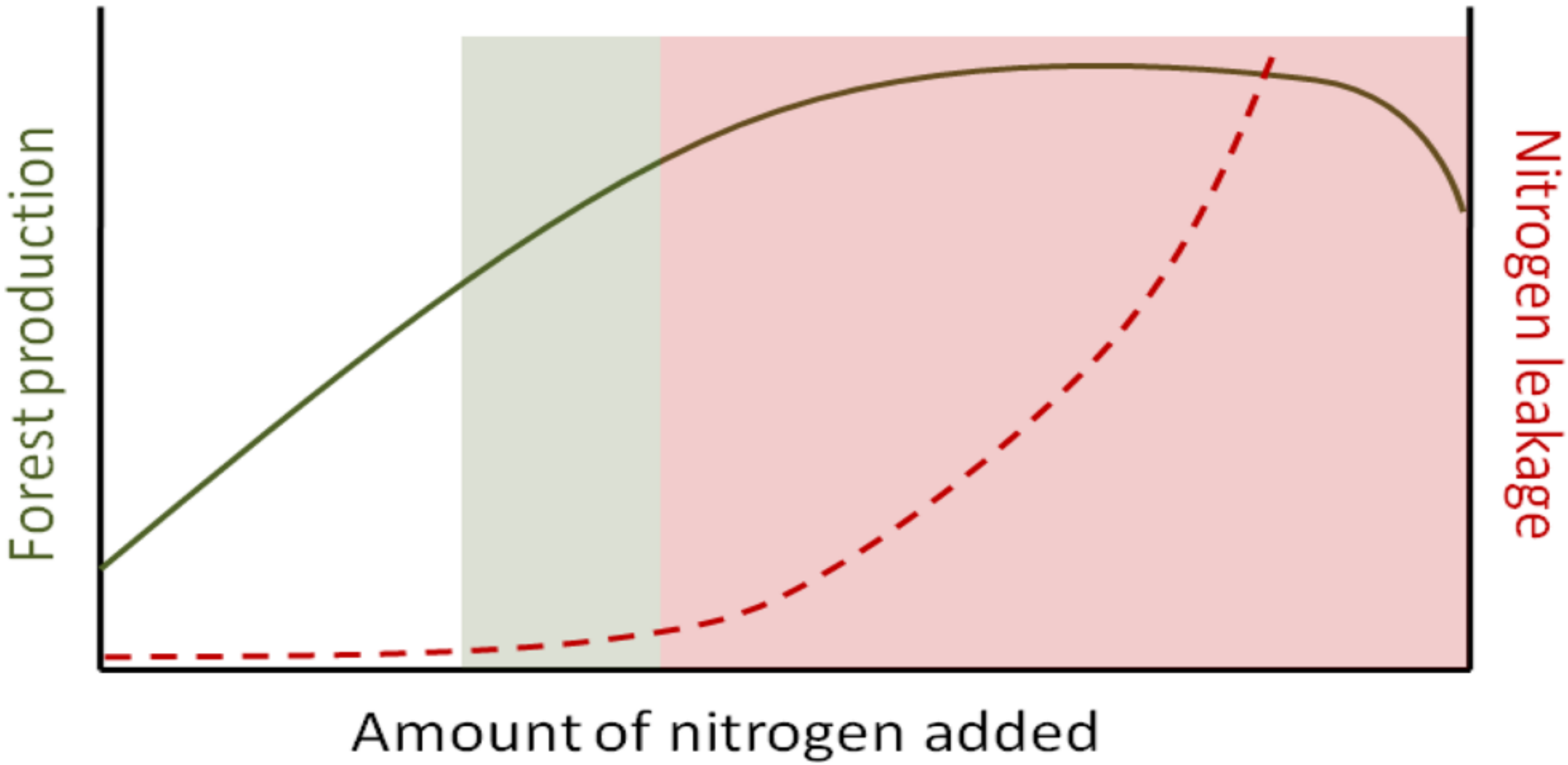
Nitrogen control over decomposition

Sara L. Jackrel, J. Timothy Wootton 2015



Effects of innate and experimentally induced variation in C : N of red alder leaves on the leaf decomposition rates in streams (*a*) and forest soil (*b*). Carbon : nitrogen ratios of leaves at the time of leaf pack deployment after the implementation of a herbivory treatment (hollow) versus control (filled) and a phosphorus fertilizer treatment (circles) versus control (squares). Coefficients of determination and two-tailed *p*-values are reported for the entire dataset.

Inputs and outputs of N x forest production



Sources of N - Ecosystems

- The N cycling in ecosystems is originally derived from three main sources:

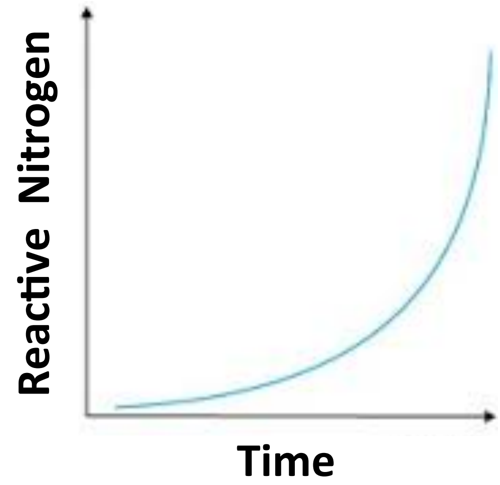
1. **Biological N fixation (BNF)** = represents the introduction of new reactive N (Nr) into the system
2. **Mineralization** = conversion of organic Nr to inorganic Nr within the system
3. **Atmospheric deposition** = transfer of Nr from one system to another.

Reactive x unreactive N

- The term reactive N (Nr) includes all biologically active, chemically reactive, and radiatively active N compounds in the atmosphere and biosphere of the Earth.

- Thus Nr includes, in contrast to unreactive N2 gas:
  - inorganic reduced forms of N (e.g., NH3, NH4.),
  - inorganic oxidized forms (e.g., NOx, HNO3, N2O, NO3),
  - organic compounds (e.g., urea, amines, proteins)

Increases in Reactive Nitrogen



Reactive Nitrogen in the atmosphere

Fossil fuel combustion

Agriculture

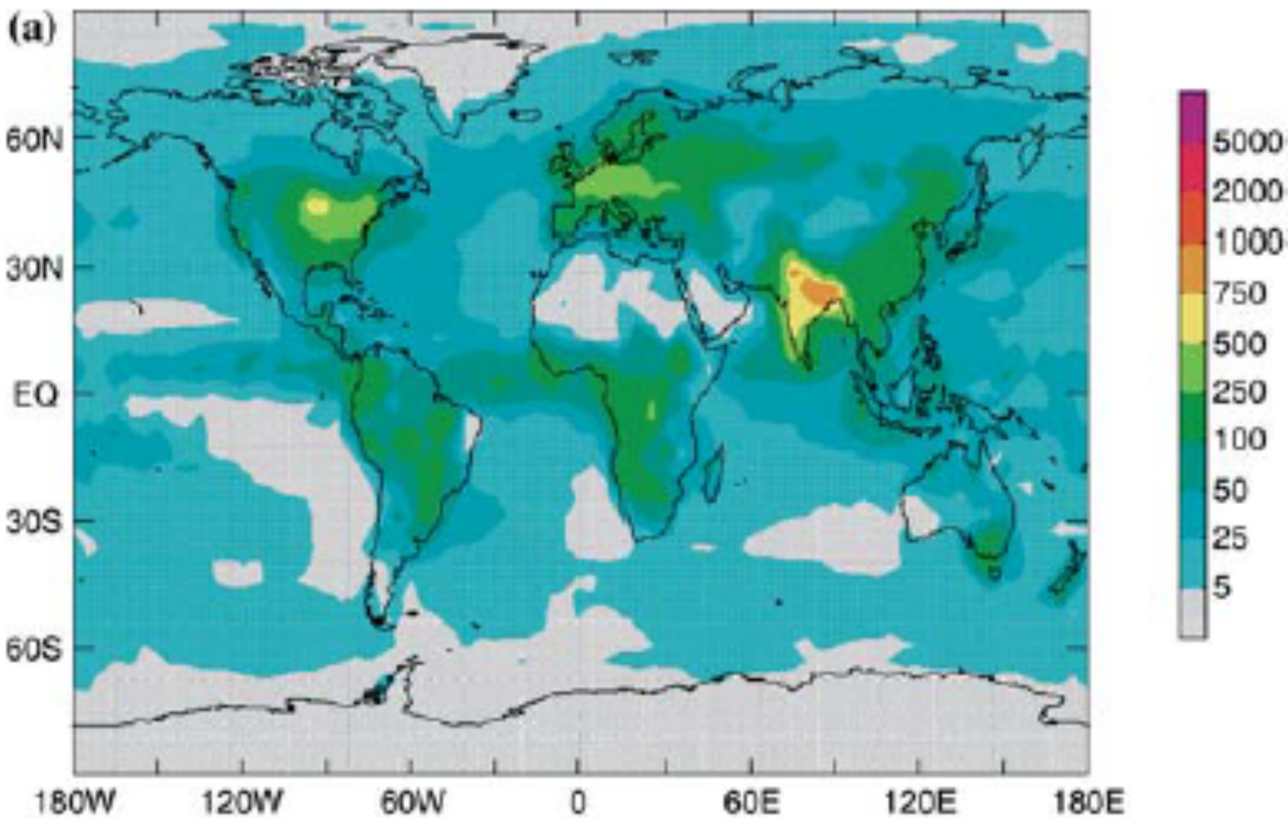
Reactive x unreactive N

- In the natural world before the agricultural and industrial revolutions, atmospheric deposition was a relatively unimportant source.

- In the current world, **atmospheric deposition is not only an important source, but it can also be the dominant source** (Galloway et al. 2008).

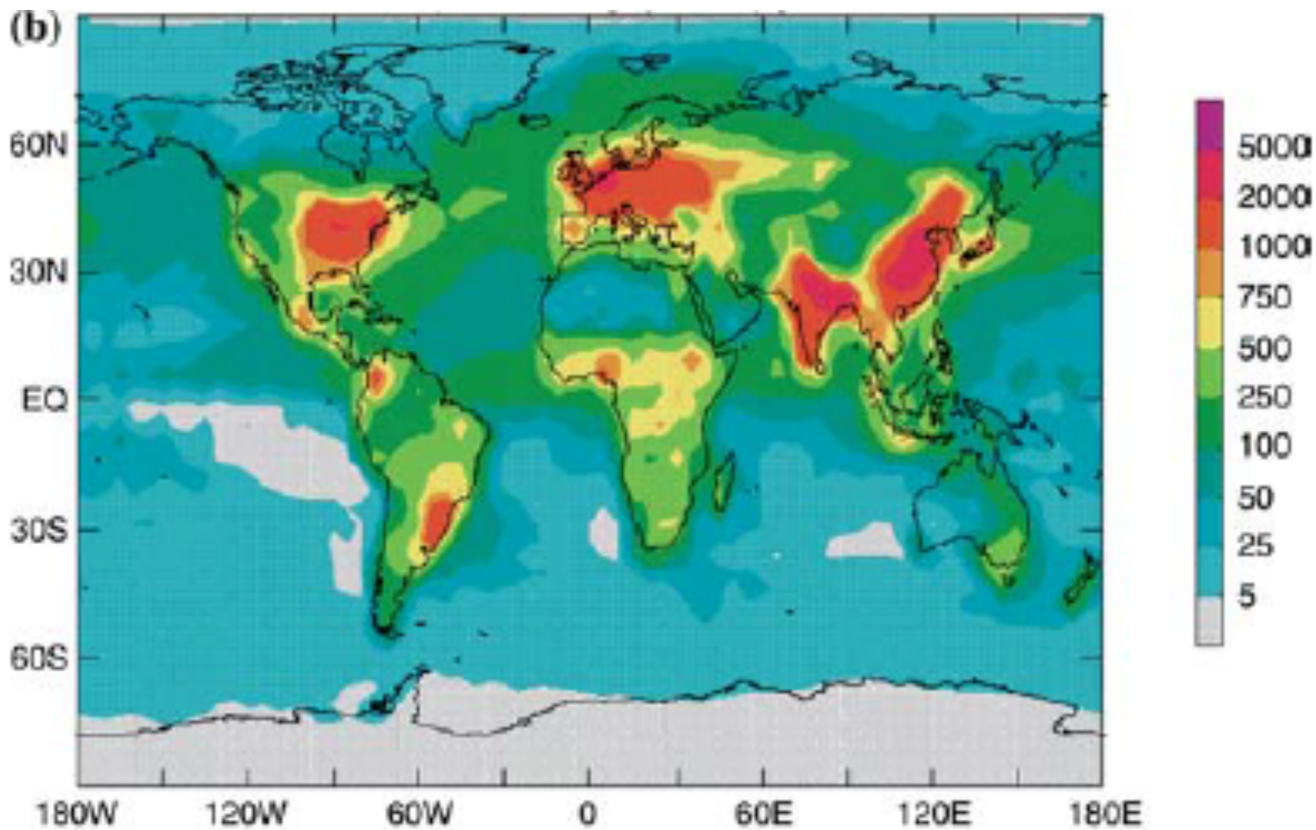
Spatial patterns of total inorganic nitrogen deposition (mg N/m^2/y)

1860



Source: Galloway *et al*., (2004). Nitrogen cycles: past, present, and future. *Biogeochemistry* 70:153-226

1993



(b)
60N
30N
EQ
30S
60S
180W
120W
60W
0
60E
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2000
1000
750
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250
100
50
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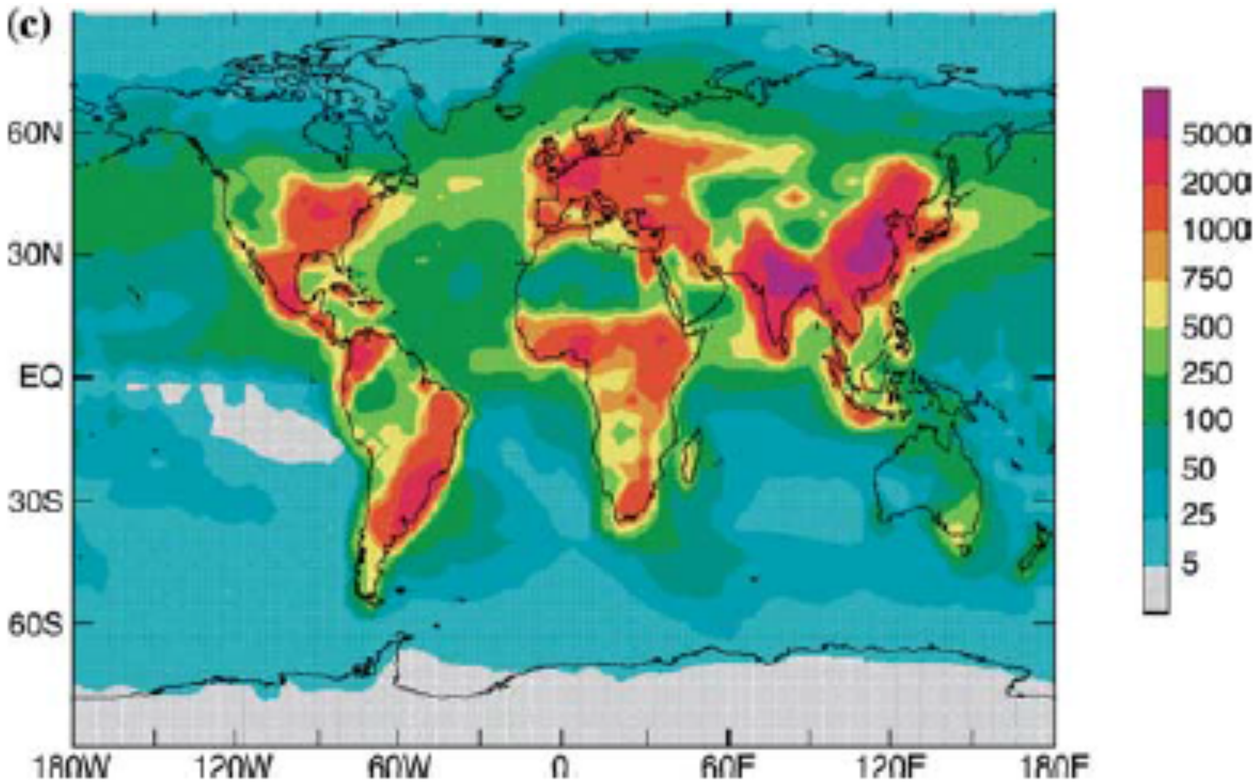
5

2050


(c)
60N
30N
EQ
30S
60S
180W
120W
60W
0
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100
50
25
5

Changes N global cycle

- Anthropogenic Nr can be emitted to the atmosphere as NOx, NH_3, and organic N.
  - major NOx sources are combustion of fossil fuels and biomass;
  - major NH_3 sources are emissions from fertilizer and manure;
  - major organic N sources are more uncertain but include both natural and anthropogenic sources.

Changes N global cycle

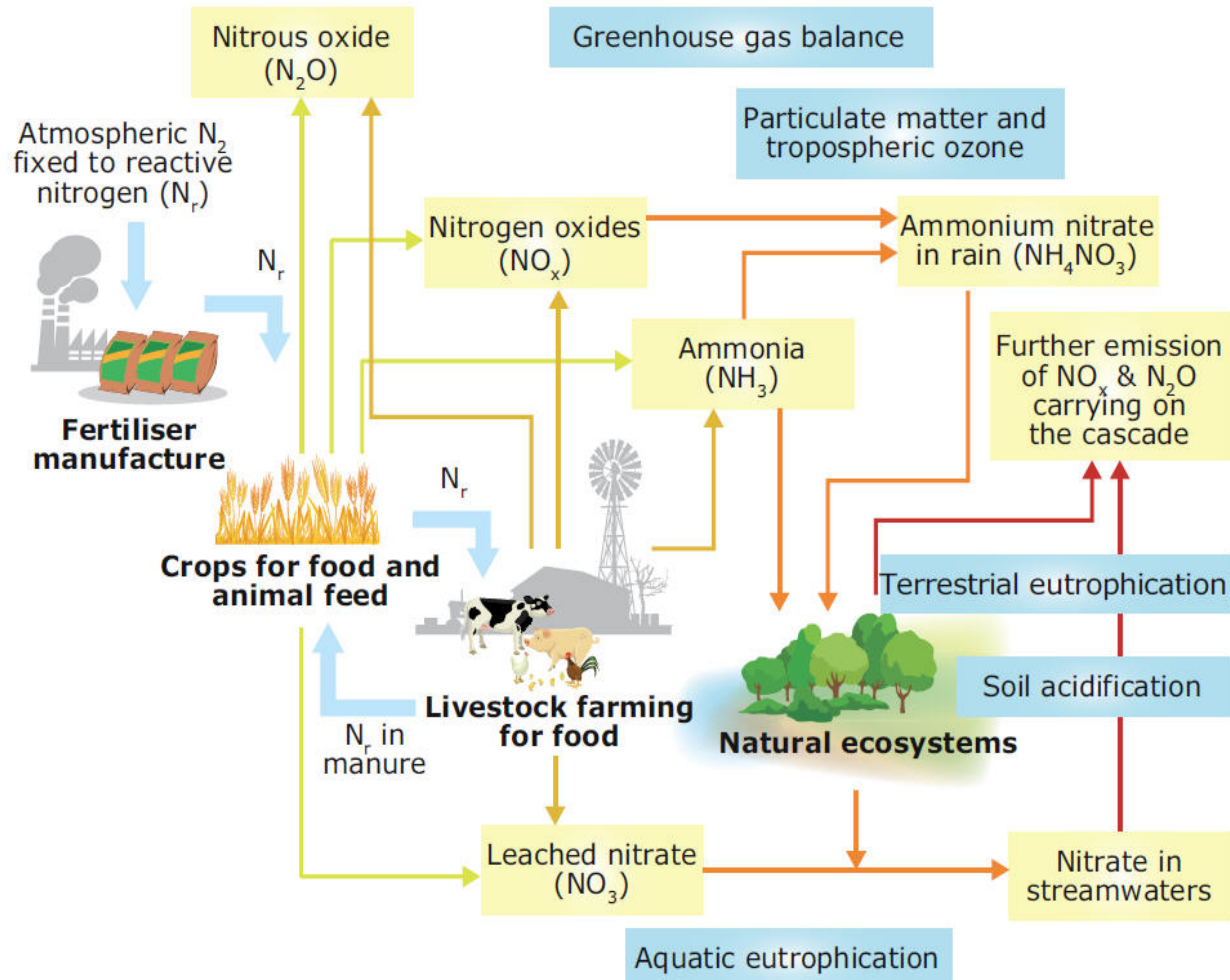
- With the exception of N_2O, all of the Nr emitted to the atmosphere is deposited to the Earth's surface following transport through the atmosphere.

- Atmospheric N transport ranges in scale from tens to thousands of kilometers.

Changes N global cycle

- The subsequent deposition often represents the introduction of reactive N to N-limited ecosystems (both terrestrial and marine) that have no internal sources of anthropogenic N.

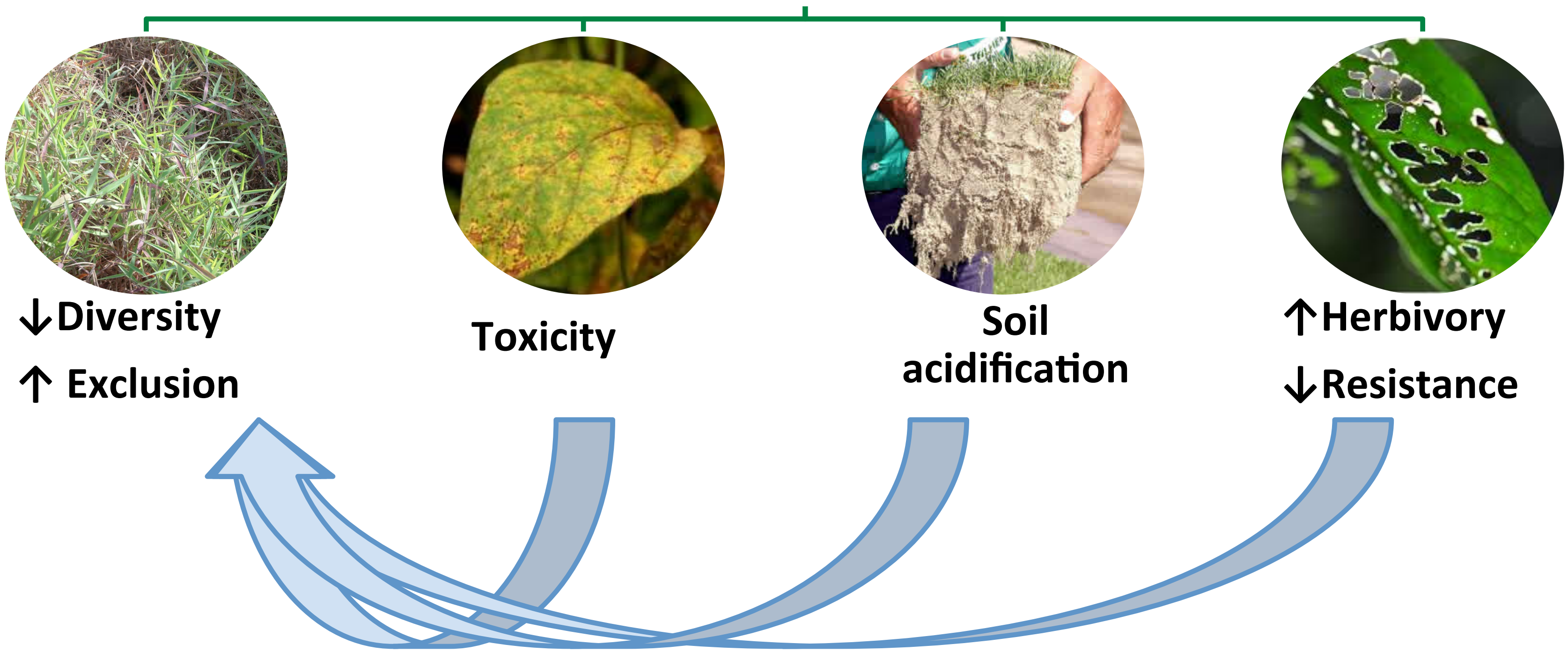
- This sets the stage for **multiple impacts on the biodiversity of the receiving ecosystems**.


Nitrous oxide (N_2O)
Greenhouse gas balance
Particulate matter and tropospheric ozone
Atmospheric N_2 fixed to reactive nitrogen (N_r)
N_r
Nitrogen oxides (NO_x)
Ammonium nitrate in rain (NH_4NO_3)
Ammonia (NH_3)
Further emission of NO_x & N_2O carrying on the cascade
Fertiliser manufacture
N_r
Crops for food and animal feed
Terrestrial eutrophication
Soil acidification
N_r in manure
Livestock farming for food
Natural ecosystems
Leached nitrate (NO_3)
Nitrate in streamwaters
Aquatic eutrophication

Increase in atmospheric N deposition is considered one of the most important components of global change, threatening the structure and functioning of ecosystems

Example:

Impacts of N deposition

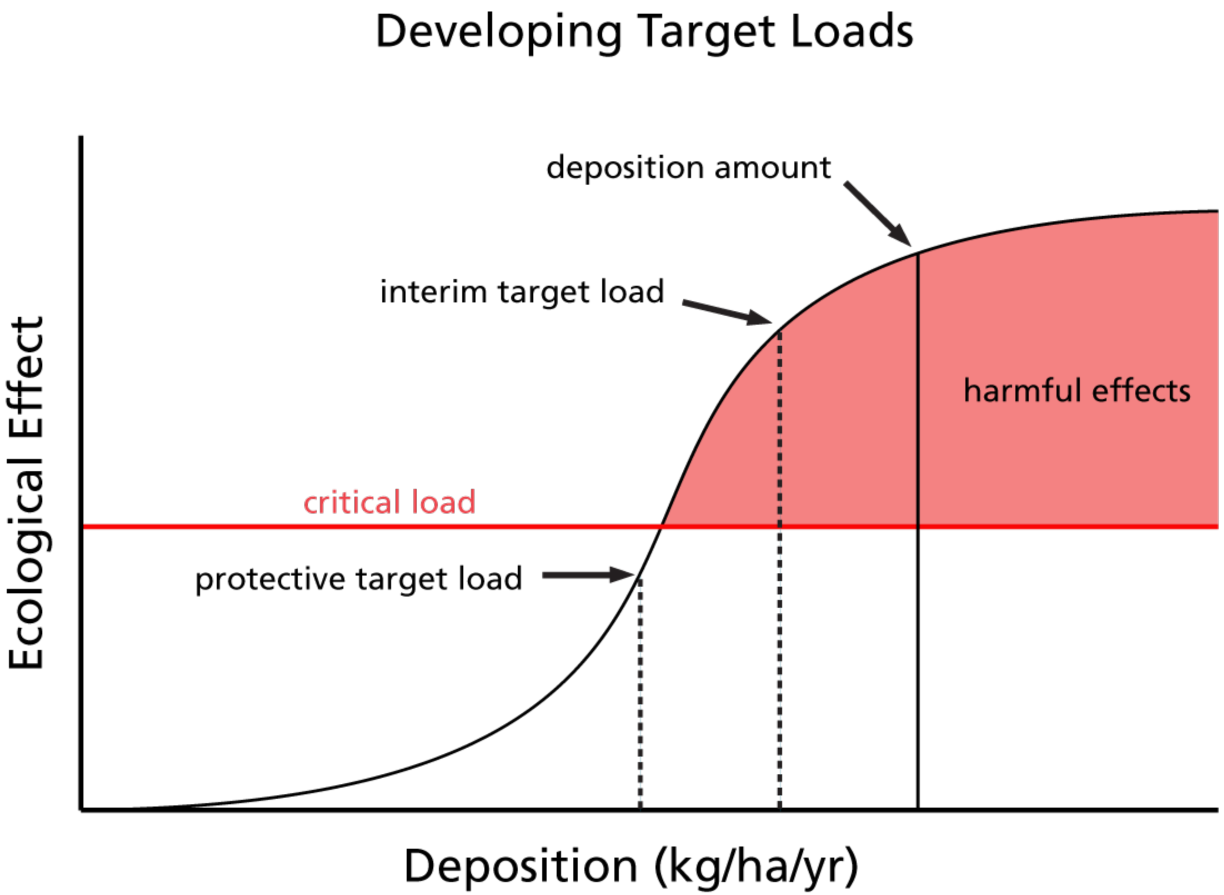


Critical load

- Critical loads are defined as ''**a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge**''.

- They are most commonly used in connection with deposition of atmospheric pollutants, particularly acidity and N, and define the maximum deposition flux that an ecosystem is able to sustain in the long term.

Critical load



Critical load

- Three approaches are currently used to define critical loads of N.

- 1o**. steady-state models** - use observations or expert knowledge to determine chemical thresholds (e.g., N availability, N leaching, C/N ratio) in environmental media for effects in different ecosystems, including changes in species composition.

Critical load

- 2o. **Empirical critical N loads** are set based on field evidence.
- Empirical critical N loads are fully based on observed changes in the structure and function of ecosystems, primarily in species abundance, composition and/or diversity, and are evaluated for specific ecosystems.

Critical load

- 3o. **Based on dynamic models**, which are developed for a prognosis of the long-term response of ecosystems to deposition, climate, and management scenarios, and can be used in an inverse way.

N deposition on Biodiversity hotspots

- Increased atmospheric nitrogen (N) deposition is known to reduce plant diversity in natural and semi-natural ecosystems.
- However our understanding of these impacts comes almost entirely from studies in northern Europe and North America.
- In particular, rates of N deposition within the newly defined 34 world biodiversity hotspots, to which 50% of the world's floristic diversity is restricted, has not been quantified previously.

Phoenix et al. Global Change Biology (2006) 12, 470–476

N deposition on Biodiversity hotspots

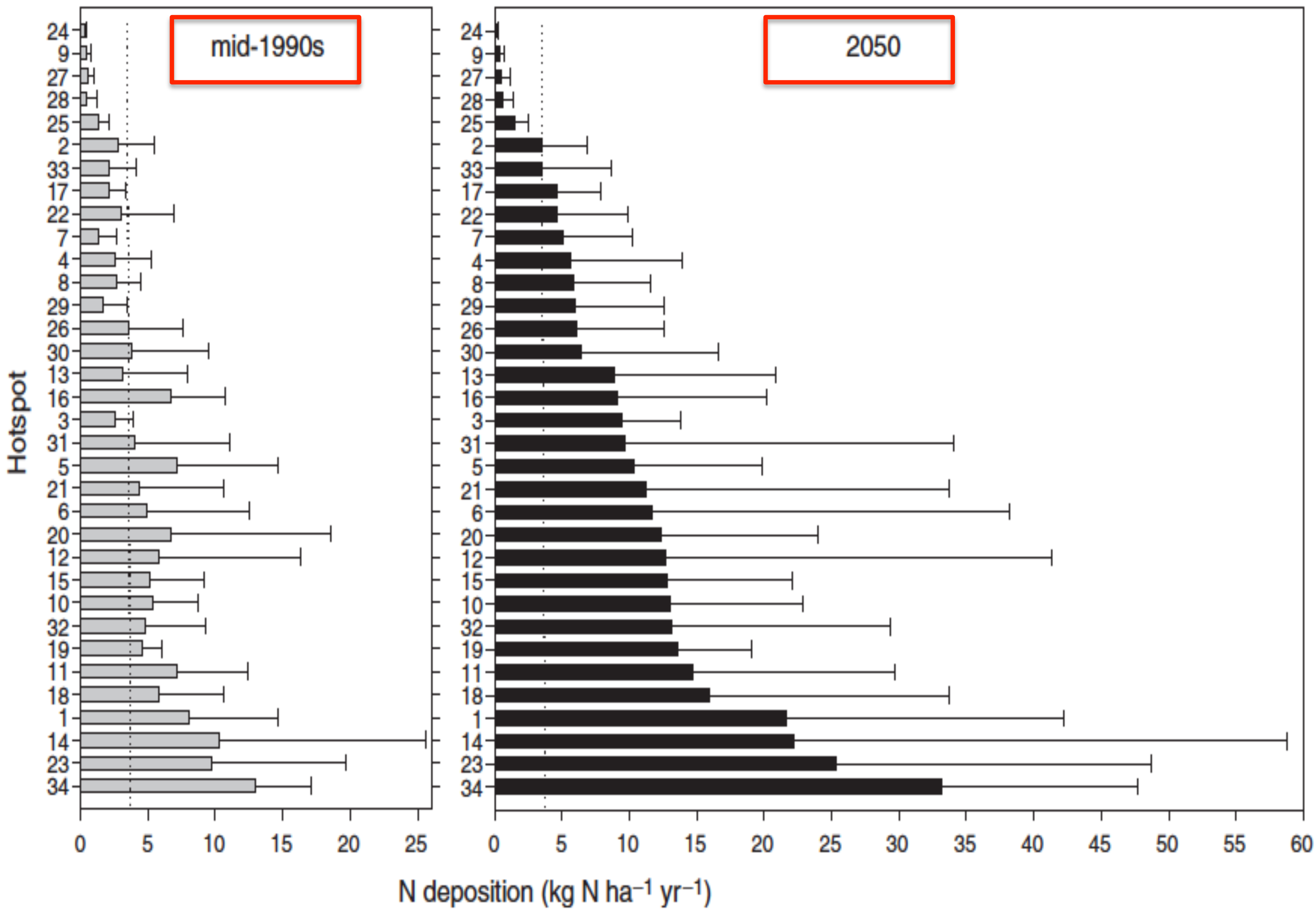
- Phoenix et al. 2006 used output from global chemistry transport models and provide estimates of mid-1990s and 2050 rates of N deposition within biodiversity hotspots:

1. Average deposition rate across these areas was 50% greater than the global terrestrial average in the mid-1990s and could more than double by 2050, with 33 of 34 hotspots receiving greater N deposition in 2050 compared with 1990.

2. By this time, 17 hotspots could have between 10% and 100% of their area receiving greater than 15 kgNha1 yr1, a rate exceeding critical loads set for many sensitive European ecosystems.

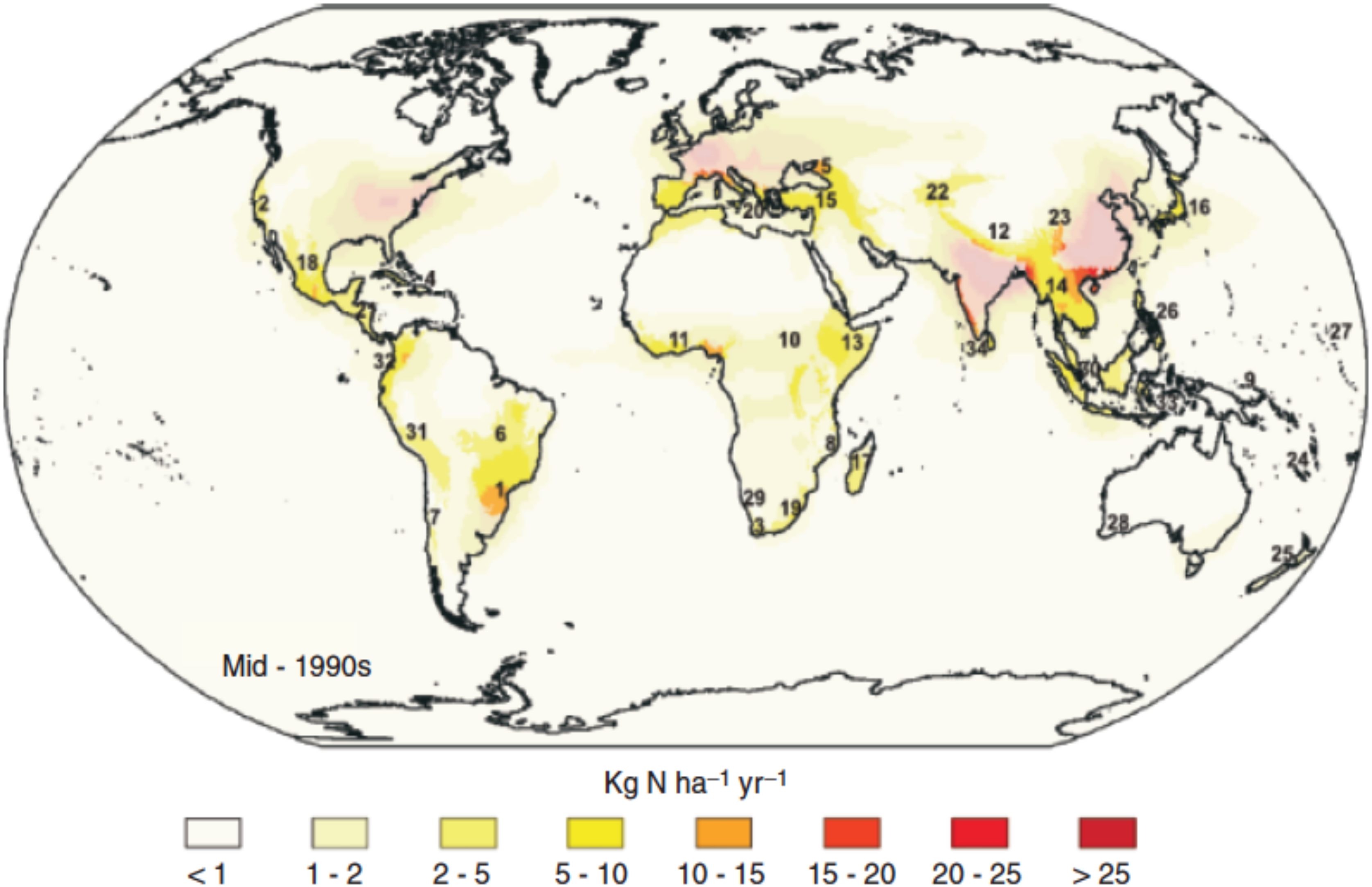
3. Average deposition in four hotspots is predicted to be greater than 20 kgNha1 yr1.

Phoenix et al. Global Change Biology (2006) 12, 470–476



Phoenix et al. Global Change Biology (2006) 12, 470–476

Mid-1990s



Phoenix et al. Global Change Biology (2006) 12, 470–476

2050

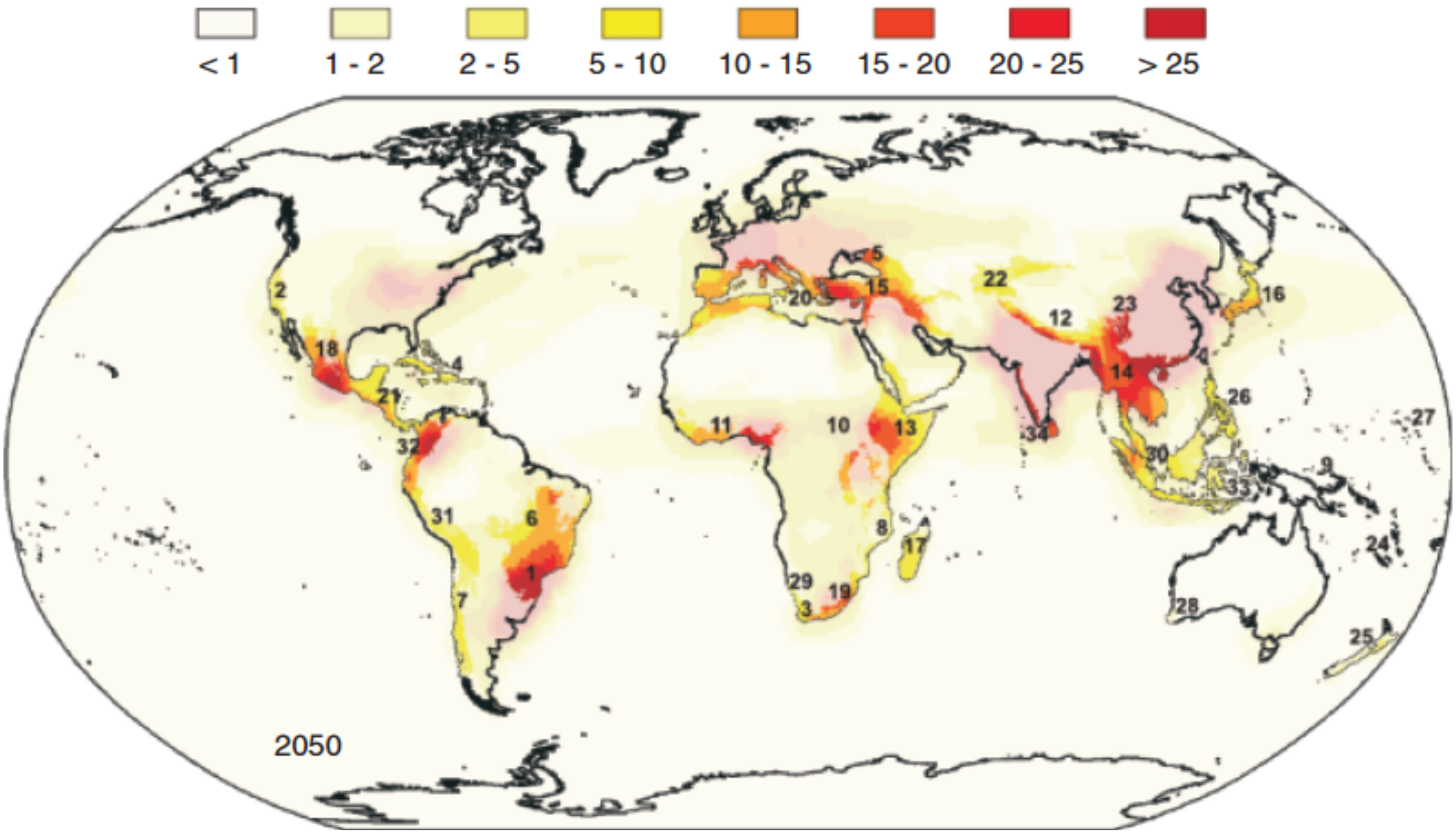


Fig. 2 Distribution of nitrogen deposition to biodiversity hotspot areas in the mid-1990s and in 2050. To aid in identification of hotspot deposition, colouring is masked (paler) for deposition outside hotspot boundaries. Hotspot boundary map copyright of Conservation International. Numbers identifying each hotspot are as for Fig. 1.

Phoenix et al. 2006

N deposition on Biodiversity hotspots

- This elevated N deposition within areas of high plant diversity and endemism may exacerbate significantly the global threat of N deposition to world floristic diversity.
- Many areas in which significant amounts of our global floristic diversity are located are likely to receive N deposition at potentially damaging rates in the near future.
- Some of these areas may already be receiving damaging rates of N deposition.
- Despite this, the lack of empirical field studies in these areas means that the sensitivity and response of hotspot vegetation remains unknown.

Phoenix et al. Global Change Biology (2006) 12, 470–476

Mechanisms of N impacts on ecological processes

- Nitrogen impacts are manifested through 5 principal mechanisms (Bobbink et al., 2010):

1. Direct toxicity of nitrogen gases and aerosols to individual species

- High concentrations in air have an adverse effect on the aboveground plant parts (physiology, growth) of individual plants.
-
- Such effects are only important at high air concentrations near large point sources.

2. Accumulation of N compounds, resulting in higher N availabilities

- This ultimately leads to changes in species composition, plant species interactions and diversity, and N cycling.
- This effect chain can be highly influenced by other soil factors, such as P limitation.

3. Long-term negative effect of reduced–N forms (ammonia and ammonium)

- Increased ammonium availability can be toxic to sensitive plant species, especially in habitats with nitrate as the dominant N form and originally hardly any ammonium.

- It causes very poor root and shoot development, especially in sensitive species from weakly buffered habitats (pH 4.5–6.5).

4. Soil-mediated effects of acidification

- This long-term process, also caused by inputs of sulfur compounds, leads to:
  - a lower soil pH, increased leaching of base cations,
  - increased concentrations of potentially toxic metals (e.g., Al3.),
  - a decrease in nitrification,
  - an accumulation of litter.

N addition and soil acidification

A global analysis of soil acidification caused by nitrogen addition / global scale and across ecosystems.

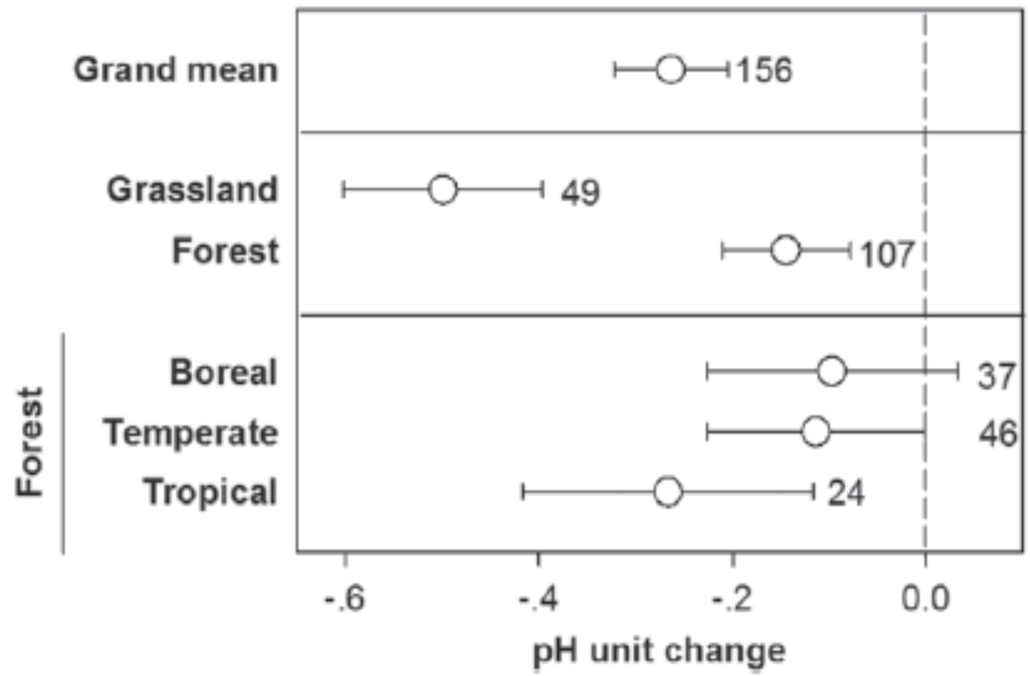


Figure 1. Soil pH unit changes with N addition at global scale and across different ecosystems. Dots represent soil pH unit changes with 95% confidence intervals (CI). If the 95% CI does not overlap 0, they are significantly affected by N addition at $\alpha = 0.05$. The dash vertical line is drawn indicating soil pH unit change = 0. The number next to the dots is the sample size of each variable. The calculation was based on the formula of $\log_{10}(H^+_{treatment}/H^+_{control}) = \log_{10}(H^+_{treatment}) - \log_{10}(H^+_{control})$, which indicates pH unit change (pHcontrol – pHtreatment) impacted by N addition. Notably, the data in the graph is presented by $pH_{treatment} - pH_{control}$.

Dashuan Tian and Shuli Niu. Environ. Res. Lett. 10 (2015) 024019

N addition and soil acidification

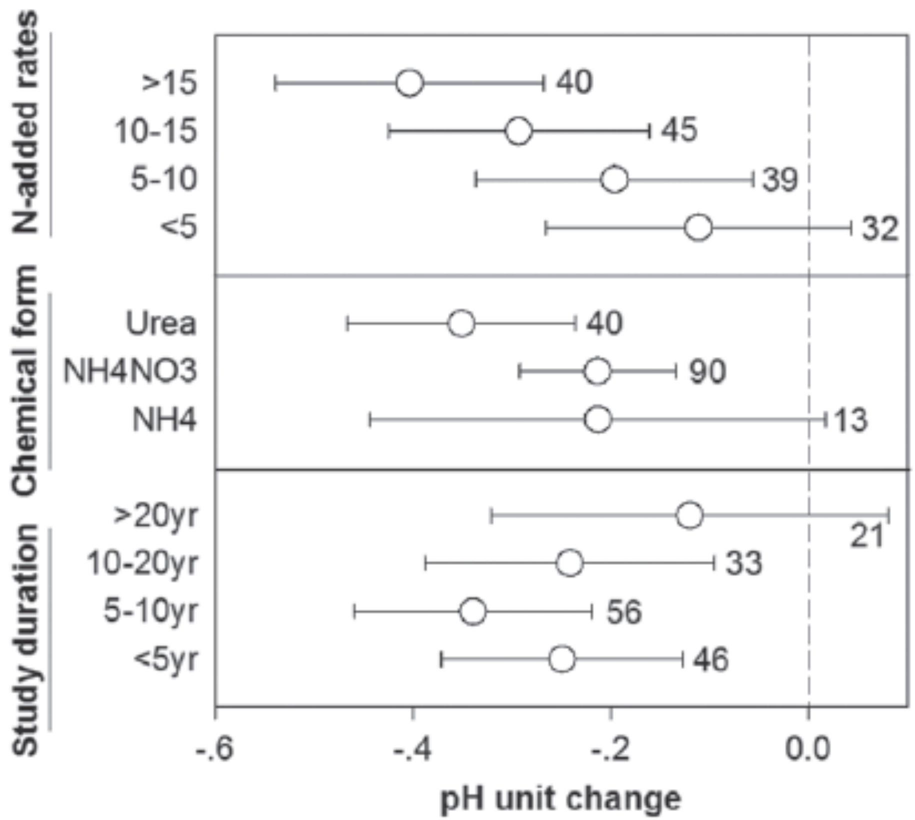


Figure 2. Soil pH unit changes with N addition rates, N-fertilizer forms and experiment durations at global scale. See the figure 1 for explanation.

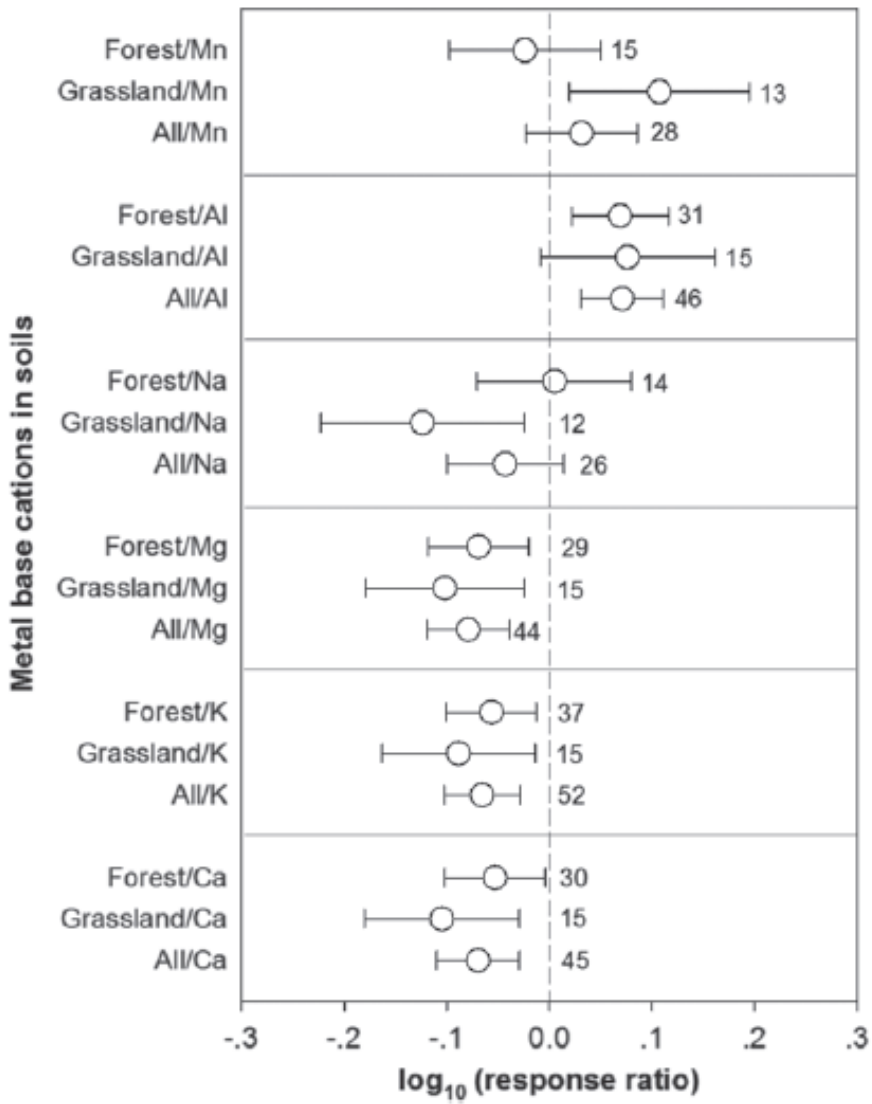


Figure 4. The weighted response ratios ($\log_{10}RR_{++}$) of soil base cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) and non-base cations (Al^{3+}, Mn^{2+}) to N addition at global scale (All) and across ecosystems (grassland, forest). Dots represent $\log_{10}RR_{++}$ with 95% confidence intervals (CI). If the 95% CI does not overlap 0, they are significantly affected by N addition at $\alpha = 0.05$. The dash vertical line is drawn indicating $\log_{10}RR_{++} = 0$. The number next to the dots is the sample size of each variable.

N addition and soil acidification

- Acid neutralizing capacity (ANC), soil nutrient availability, and soil factors which influence the nitrification potential and N immobilization rate, are especially important in this respect (Bobbink and Lamers 2002).

- For example, soil acidification caused by atmospheric deposition of S and N compounds is a long-term process that may lead to lower pH, increased leaching of base cations, increased concentrations of toxic metals (e.g., Al) and decrease in nitrification and accumulation of litter (Ulrich 1983, 1991).

- Finally, acid-resistant plant species will become dominant, and species typical of intermediate pH disappear.

5. Increased susceptibility to secondary stress and disturbance factors

- The resistance to plant pathogens and insect pests can be lowered because of lower vitality of the individuals
- Increased N contents of plants can also result in increased herbivory.
- N-related changes in plant physiology, biomass allocation (root/shoot ratios), and mycorhizal infection can also influence the susceptibility of plant species to drought or frost.

Mechanisms for plant diversity effects of increased N deposition

- Generalization of the impact of N on different ecosystems around the world is difficult
  - overall complexity of both the N cycling in ecosystems and the responses to N additions

- But there are clearly general features of the N-effect chain that can be distinguished.

- Enhanced N inputs result in a gradual increase in the availability of soil N.

- This leads to an increase in plant productivity in N-limited vegetation and thus higher litter production.

- Because of this, N mineralization will gradually increase, which may cause enhanced plant productivity

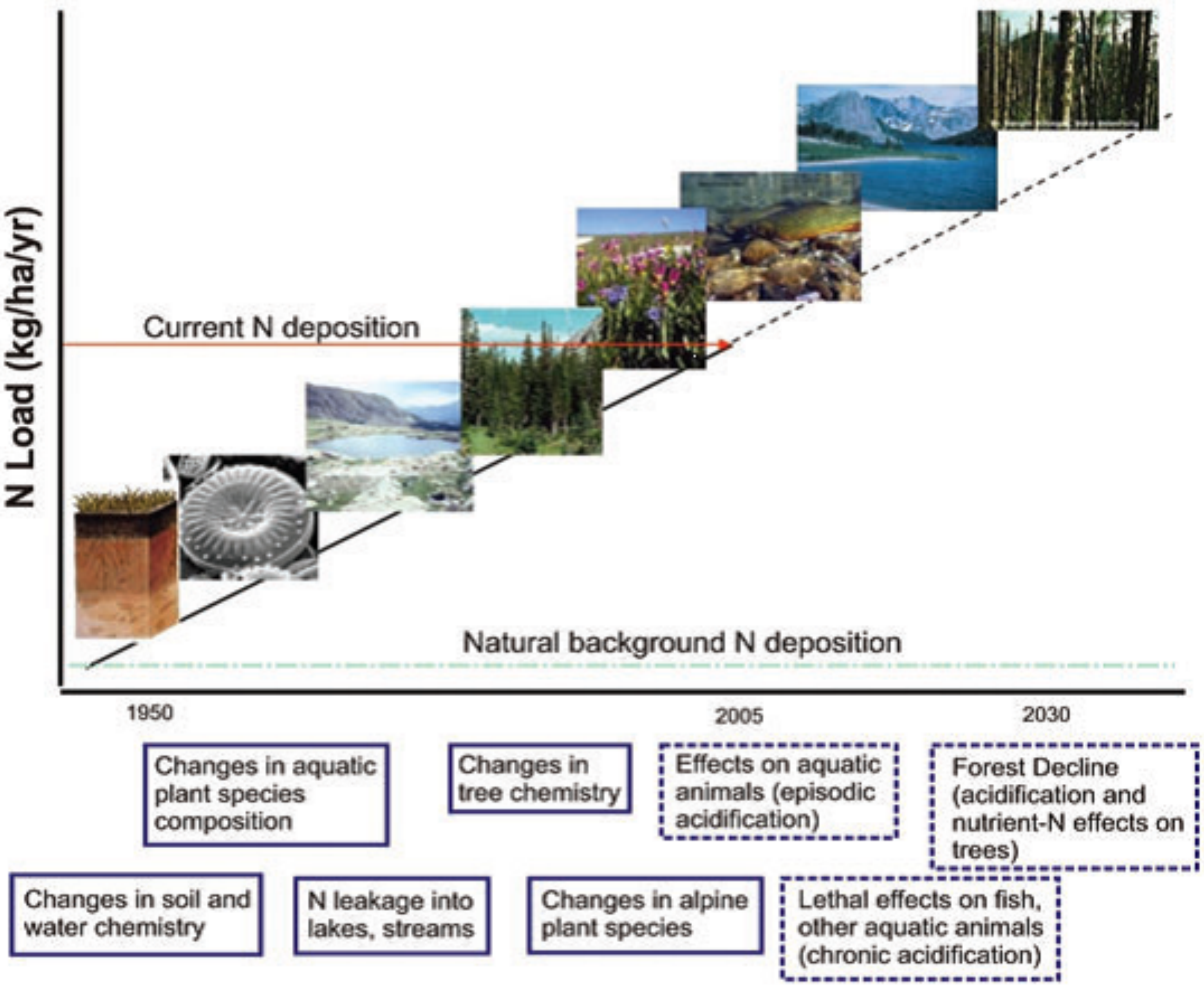
- In the longer term, competitive exclusion of characteristic species by relatively fastgrowing nitrophilic species.

In general,

- "**winners**" = nitrophilic species such as grasses, sedges and exotics
- "**losers**" = less nitrophilic species such as forbs of small stature, dwarf shrubs, lichens, and mosses

- The rate of N cycling in the ecosystem is clearly enhanced in this situation.

- Finally, the ecosystem becomes ‘‘N-saturated,’’ which leads to an increased risk of N leaching from the soil to the deeper ground water or of gaseous fluxes (N_2 and N_2O) to the atmosphere.



- Continuum of nitrogen deposition impacts demonstrated from past observations and potential future effects in Rocky Mountain National Park.

- As ecosystem nitrogen accumulation continues, additional acidification or eutrophication impacts occur to various ecosystem receptors.

- The trajectory line is conceptual even though the effects below the current nitrogen deposition level have been documented.

Similar trajectories of additional ecosystem effects as nitrogen accumulates in the ecosystem occur in other ecological regions. (Figure: Ellen Porter, National Park Service).

Loss of plant species after chronic low-level nitrogen deposition

- Clark and Tilman (2008) - Prairie grasslands
- Multi-decadal experiment to examine the impacts of chronic, experimental nitrogen addition as low as 10 $kgNha^{-1}\ yr^{-1}$ above ambient atmospheric nitrogen deposition (6 $kgNha^{-1}$ yr at our site).
- Chronic low-level nitrogen addition rate reduced plant species numbers by 17% relative to controls receiving ambient N deposition.

Moreover, species numbers were reduced more per unit of added nitrogen at lower addition rates, suggesting that **chronic but low-level nitrogen deposition may have a greater impact on diversity** than previously thought.

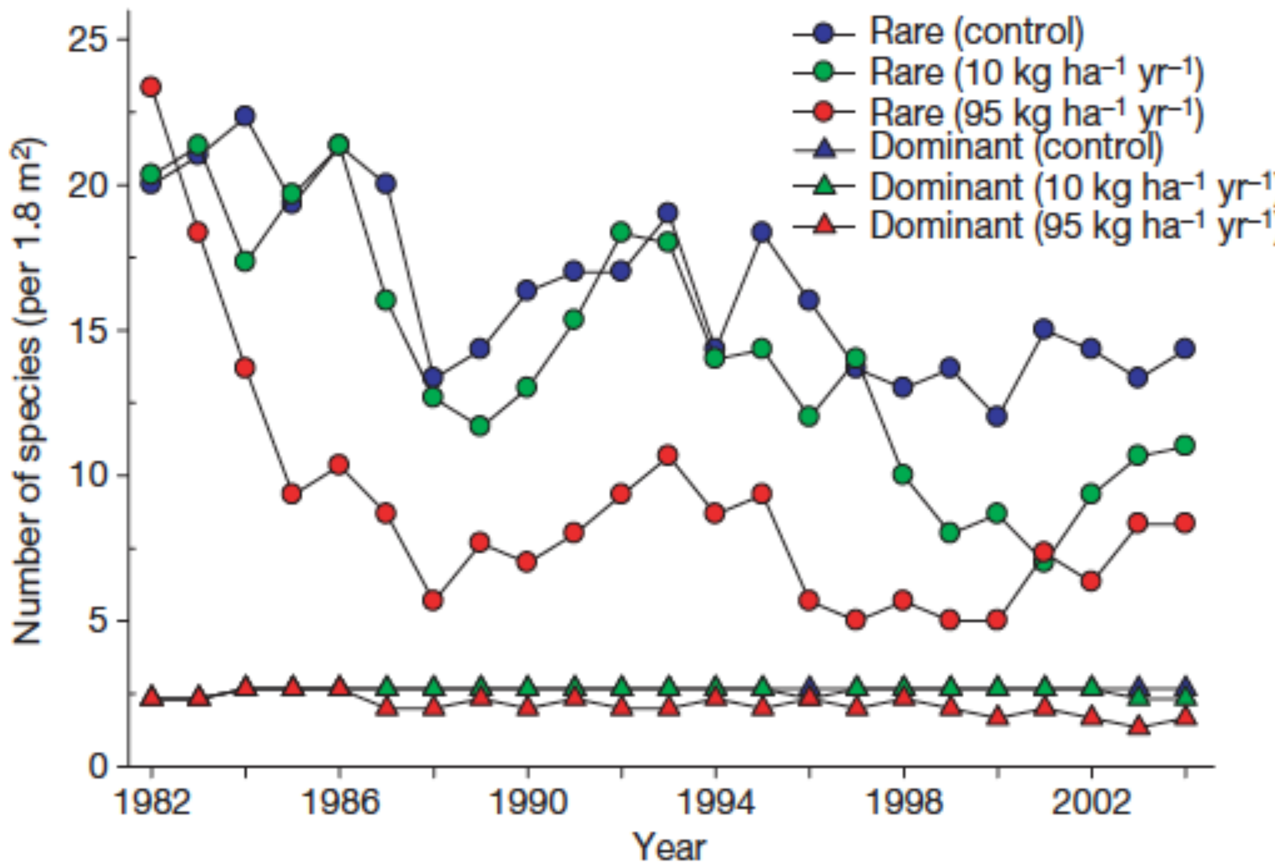


Figure 3 | Losses of rare versus dominant species. Dynamics of the numbers of rare and dominant species, expressed as the total numbers of such species across all replicates of a treatment in a field (see Methods). The average number across all fields of rare and dominant species in the controls (no added nitrogen) and in the lowest and the highest nitrogen addition treatments is shown. For clarity, intermediate nitrogen treatments and subordinate species are not shown, but demonstrated intermediate results.

Clark and Tilman. Nature Vol 451|7 2008

Second experiment: cessation of N addition

- a decade after cessation, relative plant species number, although not species abundances, had recovered, demonstrating that **some effects of nitrogen addition are reversible**.

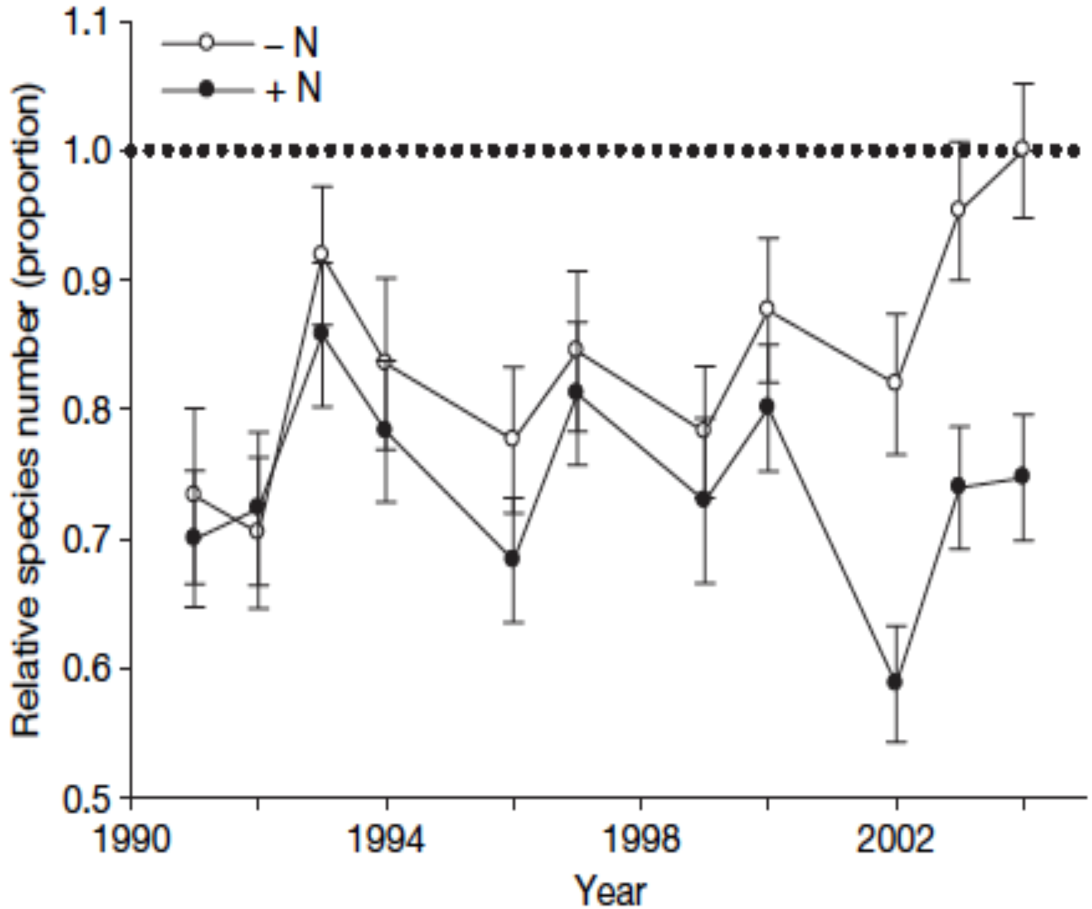


Figure 4 | Recovery of relative species number after cessation of nitrogen addition. Relative species number of all plots that continued to receive nitrogen (+N) and of those plots for which nitrogen addition ceased from 1991 and on (−N) is shown as the average across all nitrogen addition levels each year (± s.e.m.). There were no significant interactions between the rate of nitrogen addition and either year or the cessation treatment (Supplementary Information).

Clark and Tilman (2008)

Nitrogen an Phosphorus interactions

- When the natural N deficiencies in an ecosystem are removed, plant growth becomes restricted by other resources, such as P, and productivity will not increase further.

- This is particularly important in regions such as the tropics that already have very low soil P availability.

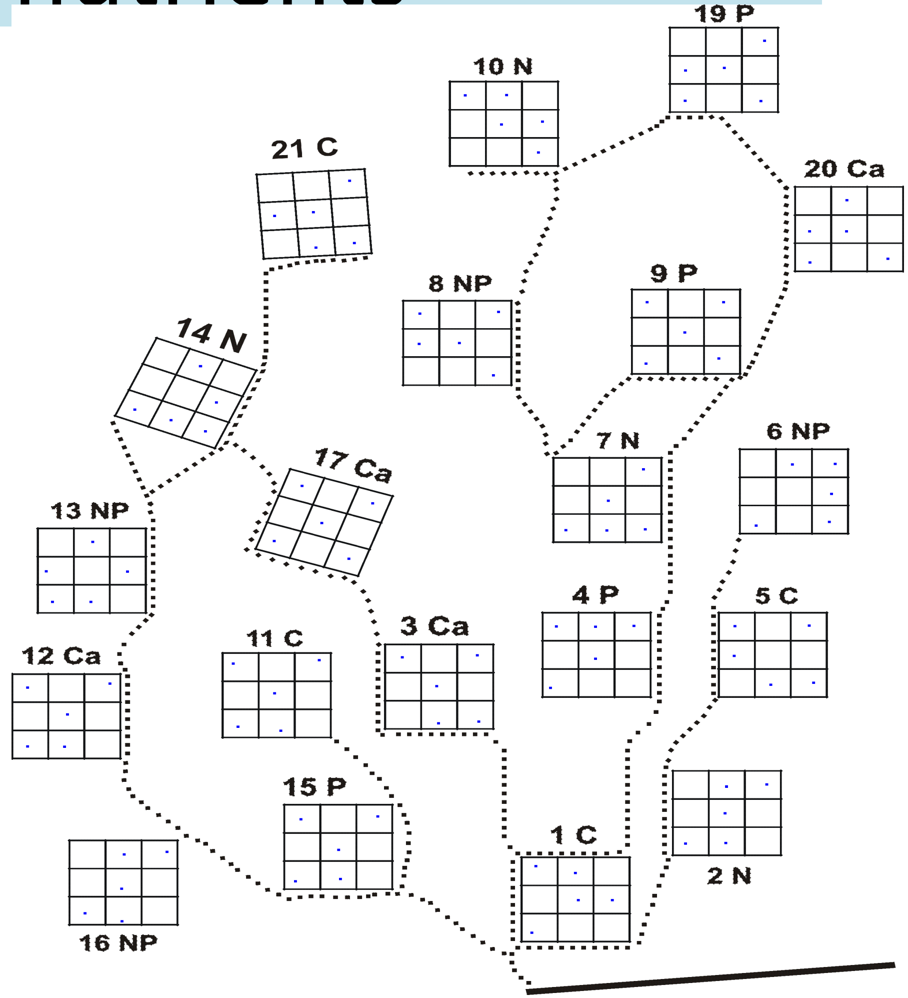
Nitrogen an Phosphorus interactions

- N concentrations in the plants will, however, increase with enhanced N inputs in these P-limited regions, which may alter
  - the palatability of the vegetation and thus cause increased risk of (insect) herbivory.
  - N concentrations in litter increase with raised N inputs, leading to extra stimulation of N mineralization rates.

- Because of this imbalance between N and P, plant species that have a highly efficient P economy gradually profit, and species composition can be changed in this way without increased plant productivity.

Fertilization experiment in a savanna limited by nutrients

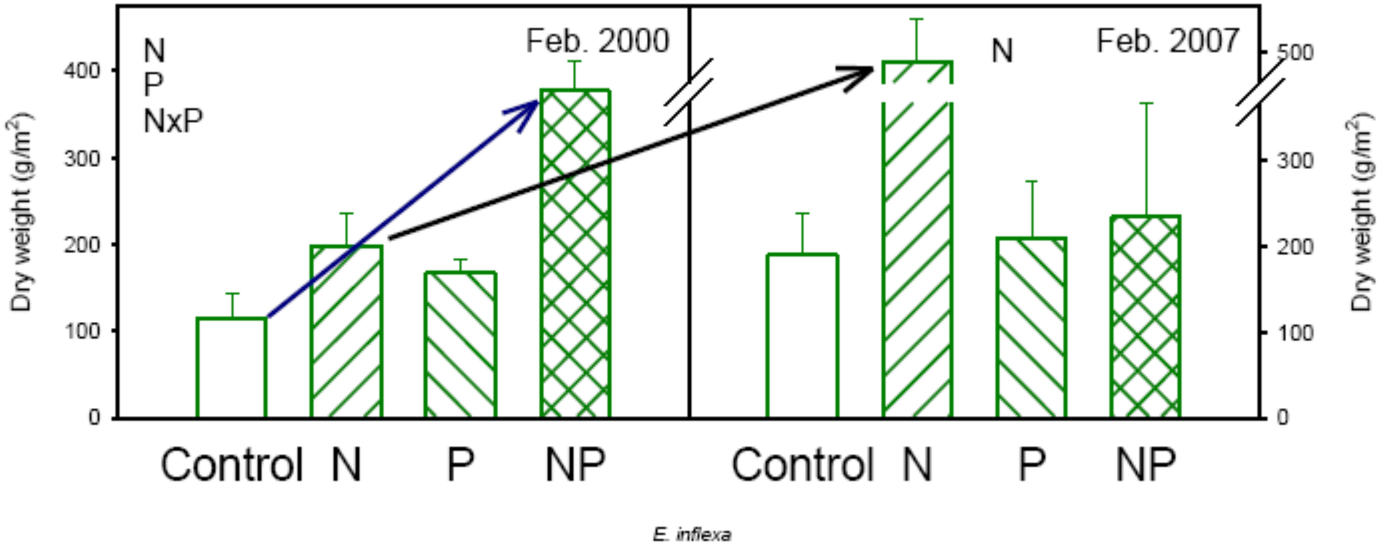
- Ecological Reserva of IBGE (Brazilian Institute for Geography and Statistics) Brasília, Federal District
- Four treatments = control, N, P and N plus P additions
- Replicated in four 225m^2 plots per treatment.
- Started in 1998
- Annual additions, divided in two applications (beginning and end of rainy season) :
- N = 100 kg.ha^{-1}.y^{-1}
- P = 100 kg.ha^{-1}.y^{-1}
- N plus P (100 kg.ha^{-1}.y^{-1} each)



Biomass of plant functional types

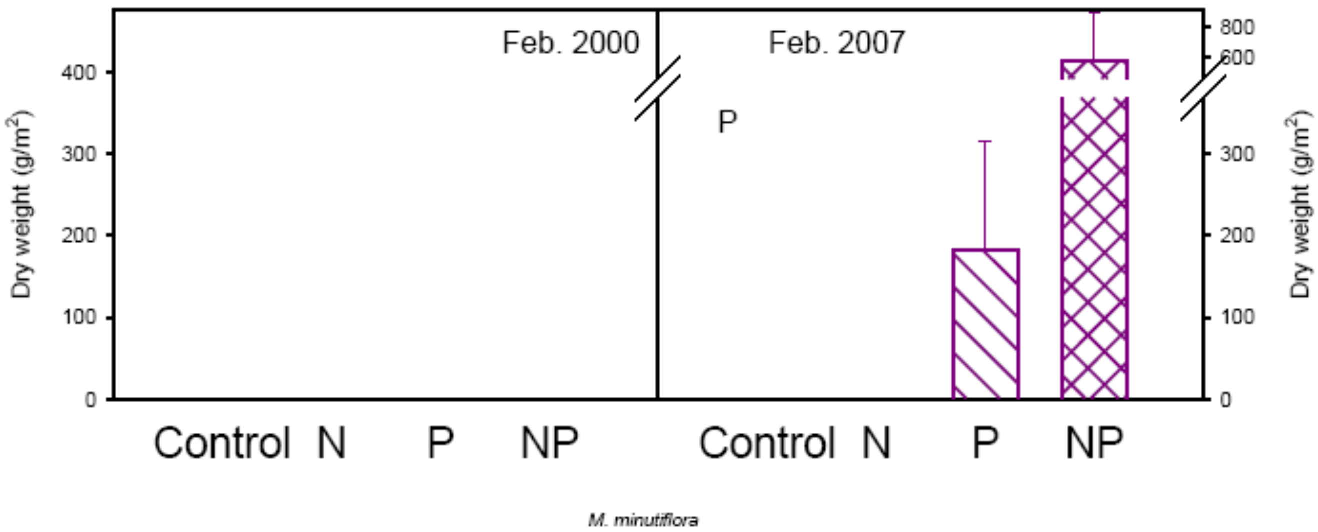
1. Dicots
2. Native C3 grass – *Echinolaena inflexa*
3. Native C4 grasses
4. African C4 grass *Melinis minutiflora*.

Biomass of the C3 grass – *E. inflexa*



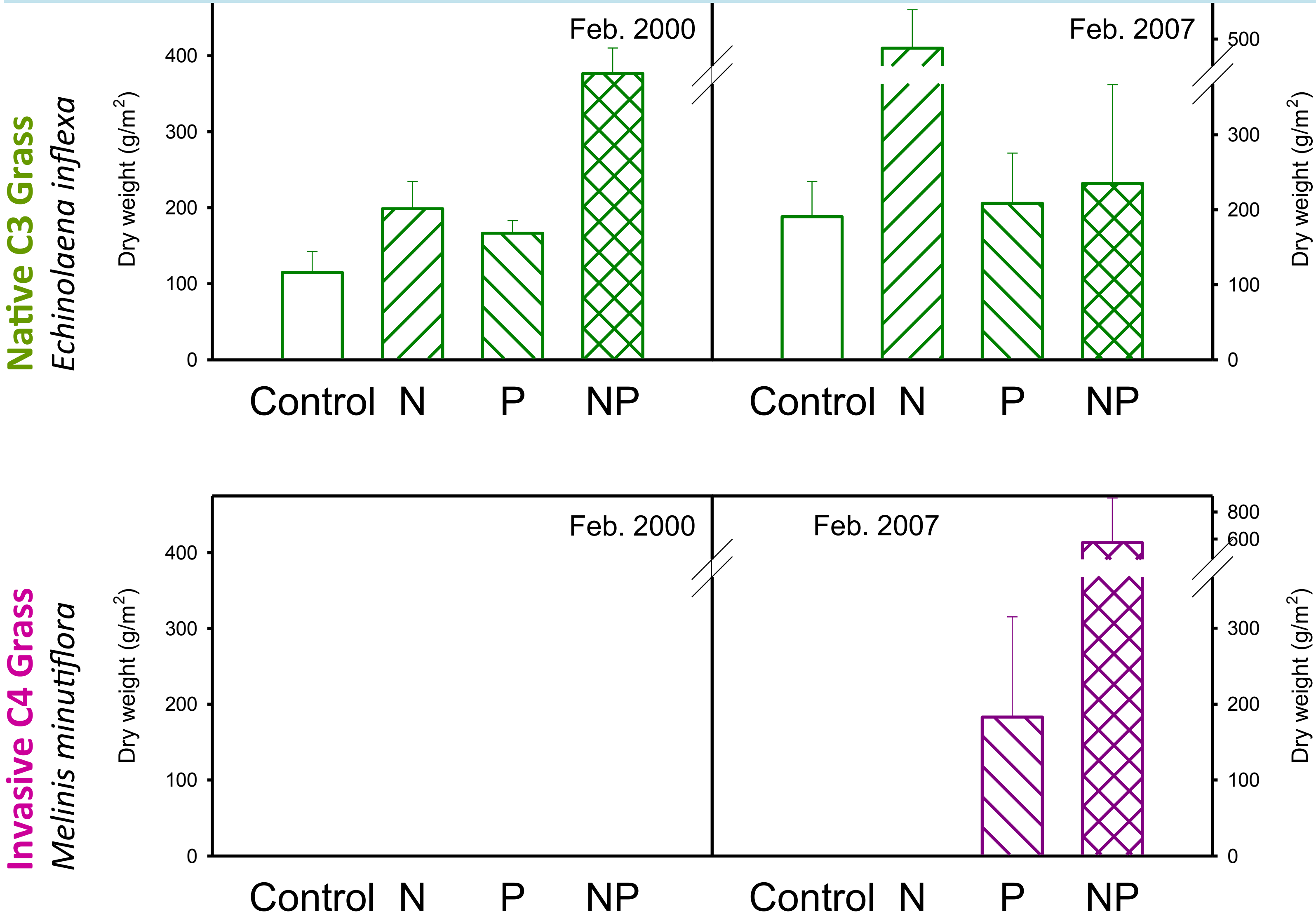
- In 1999/2000, the C3 grass *E. inflexa* responded significantly to N treatment, but had an even higher biomass under N+P.
- P alone had no effect on the C3 grass.
- In 2007, the biomass of *E. inflexa* continued to be significantly higher under N, but not under N+P. Why?

Biomass of exotic C4 grass – *M.minutiflora*



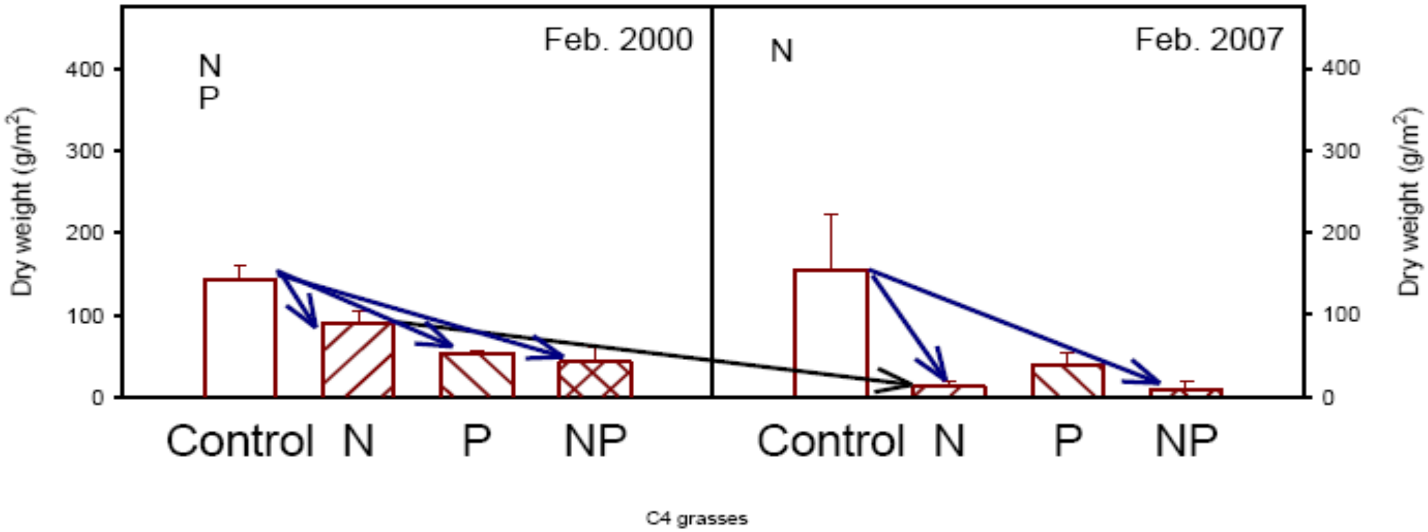
- The probable explanation is the significant effect of P addition on the alien grass *M. minutiflora* in 2007, showing its greater biomass under N+P (being virtually absent under the control condition).

Echinolea inflexa x Melinis minutiflora



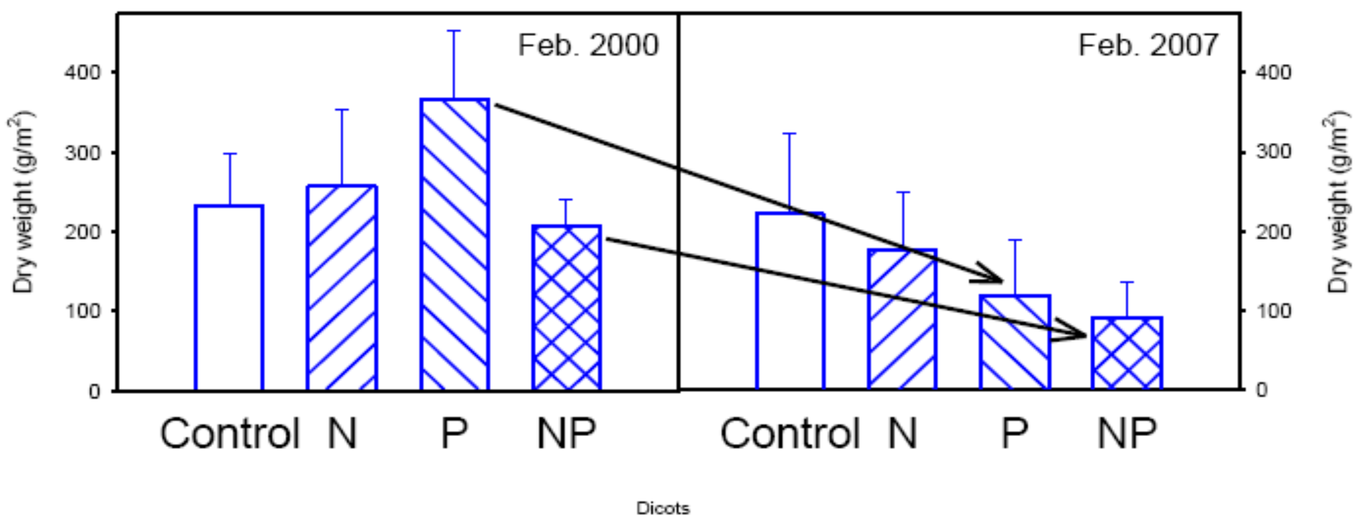
M. minutiflora

Biomass of native C4 grasses



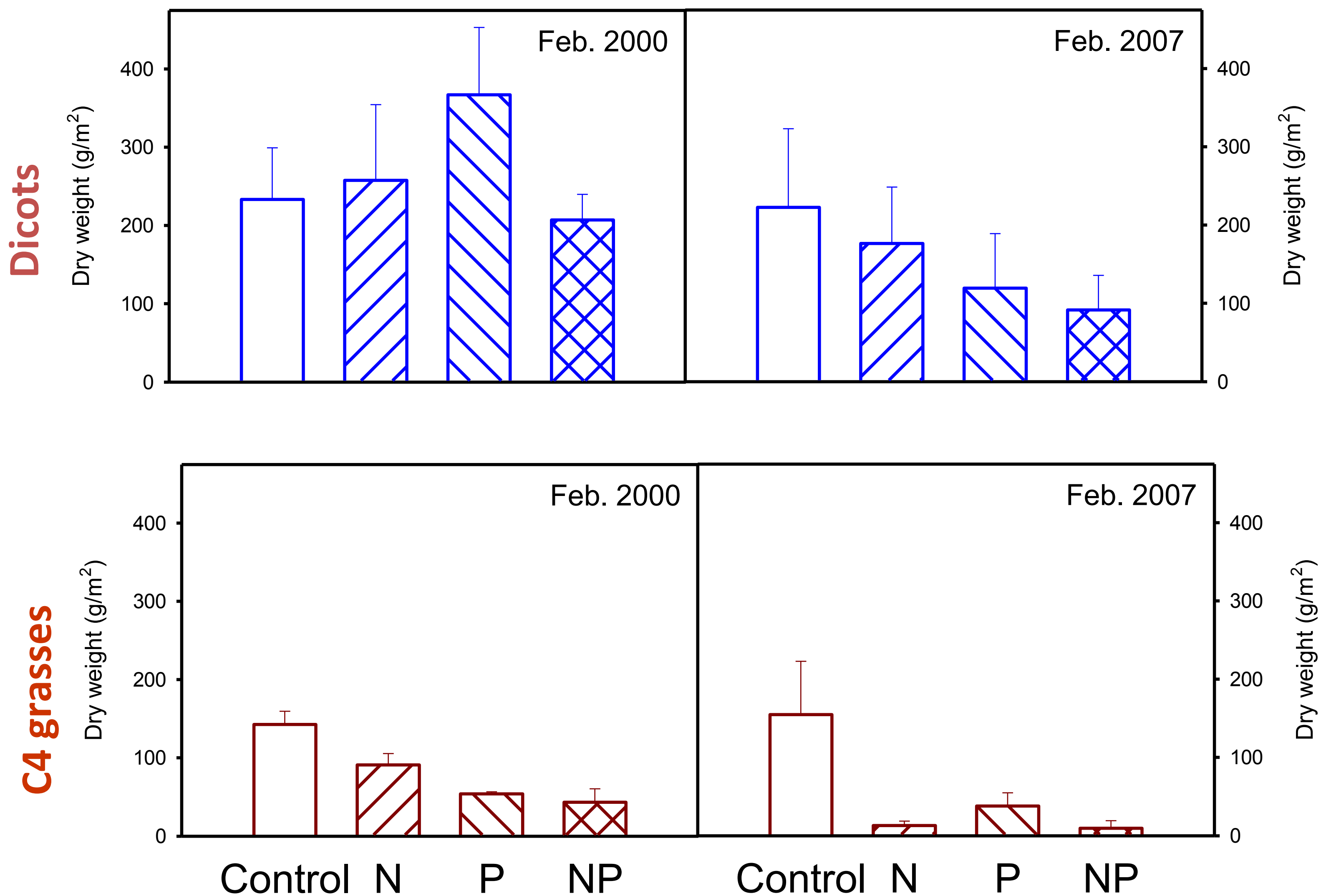
- The native C4 grasses had significantly lower biomass values under N and N+P in 2007, seeming to be displaced by the C3 grass *E. inflexa* and the alien C4 grass *M. minutiflora,* respectively.

Biomass of herbaceous dicots



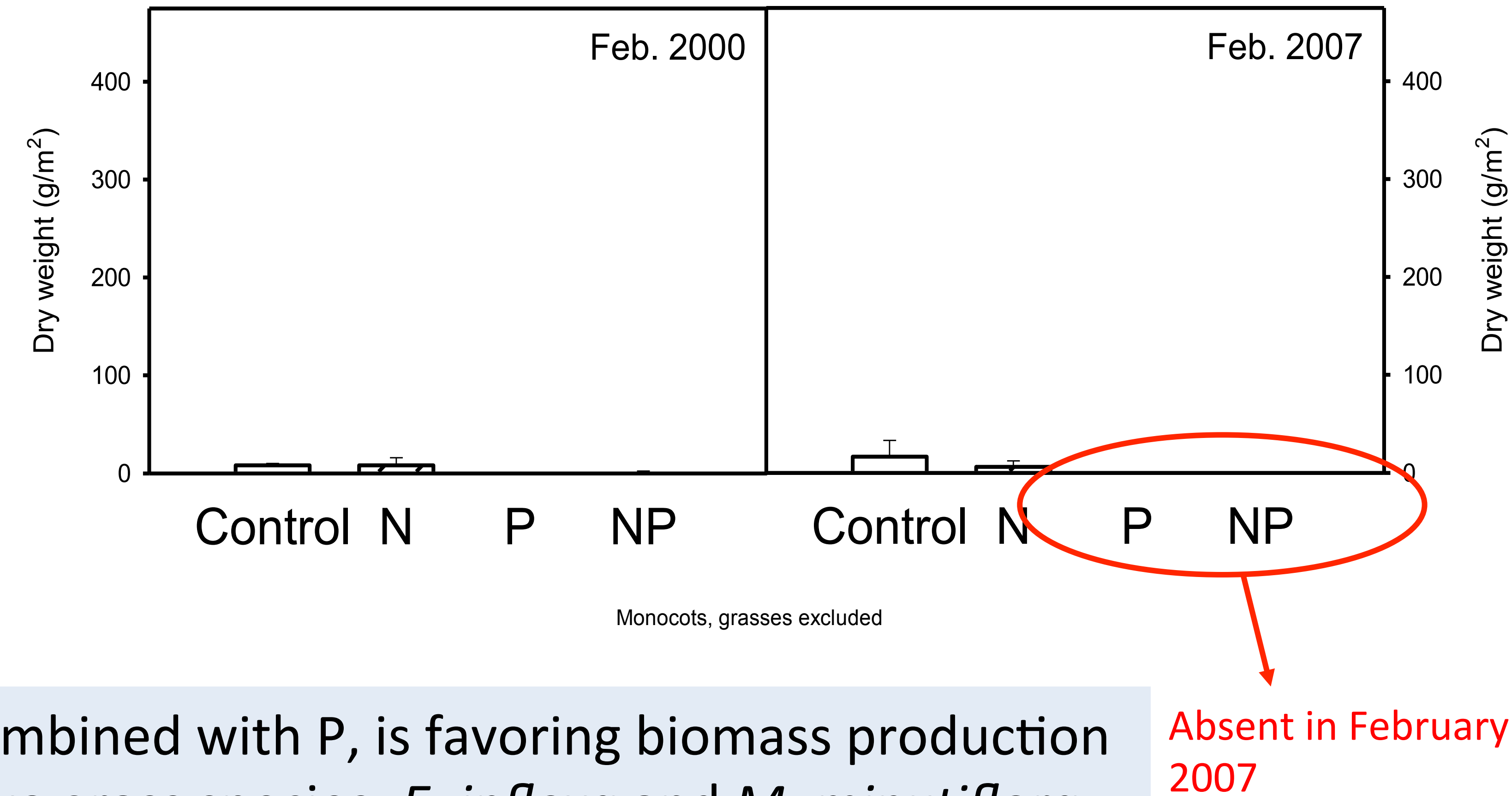
- Significant reduction after 7 years of fertilization in the P and N+P treatments.

Biomass of Dicots and C4 Native Grasses



C4 grasses

Biomass of other monocots (non grasses)



N combined with P, is favoring biomass production of two grass species: *E. inflexa* and *M. minutiflora* Decreasing the biomass of other grasses (native C4 grasses), other monocots (mainly cyperaceous) and dicots under elevated nutrient conditions.

Shifts in Lake N:P Stoichiometry and Nutrient Limitation Driven by Atmospheric Nitrogen Deposition

- Elser et al. 2009 analyzed lakes in Norway (385 lakes), in Sweden (1668 lakes) and in the central Colorado Rocky (US) that represent both high–and low–N deposition conditions.

- Determine whether elevated atmospheric N inputs affect lake phytoplankton nutrient supplies in terms of concentrations and ratios of total N (TN) and total P (TP).

SCIENCE VOL 326 6 NOV. 2009

Under low N deposition, phytoplankton growth is generally N-limited;

However, in high–N deposition lakes, phytoplankton growth is consistently P-limited.

Values greater than 1 = N limitation
Values less than 1= P limitation

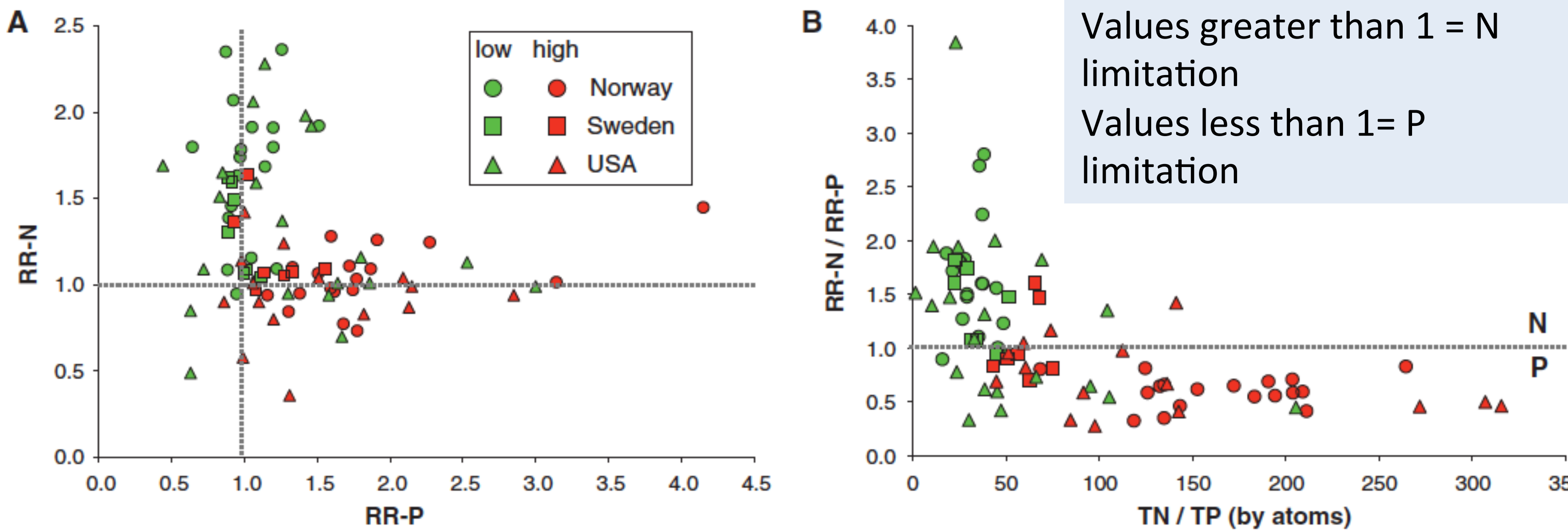


Fig. 2. Phytoplankton N and P limitation as a function of atmospheric N deposition in lakes of Norway (circles), Sweden (squares), and Colorado (triangles). Lake phytoplankton that respond strongly to N have a weak response to P and vice versa (**A**). Horizontal and vertical lines delineate response ratios of 1, indicating no response of phytoplankton biomass to enrichment of that nutrient. Results from low-deposition lakes (green) are clustered on the *y* axis, indicating primary N limitation, whereas those from high-deposition lakes (red) are clustered on the *x* axis, indicating primary P limitation. The relative phytoplankton response to N compared with P (RR-N/RR-P) is strongly dependent on lake TN:TP ratio (**B**), which itself is dependent on N deposition. Values greater than 1 indicate that N limitation predominates in that lake, whereas values less than 1 indicate that P limitation predominates.

Shifts in Lake N:P Stoichiometry and Nutrient Limitation Driven by Atmospheric Nitrogen Deposition

- Impacts of amplification of the global N cycle on biogeochemical cycling, trophic dynamics, and biological diversity, in the world's lakes, even in lakes far from direct human disturbance.

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Human-induced nitrogen–phosphorus imbalances alter natural and managed ecosystems across the globe

- Peñuelas et al. 2013

- The availability of carbon from rising atmospheric carbon dioxide levels and of nitrogen from various human-induced inputs to ecosystems is continuously increasing.

- However, these increases are not paralleled by a similar increase in phosphorus inputs.

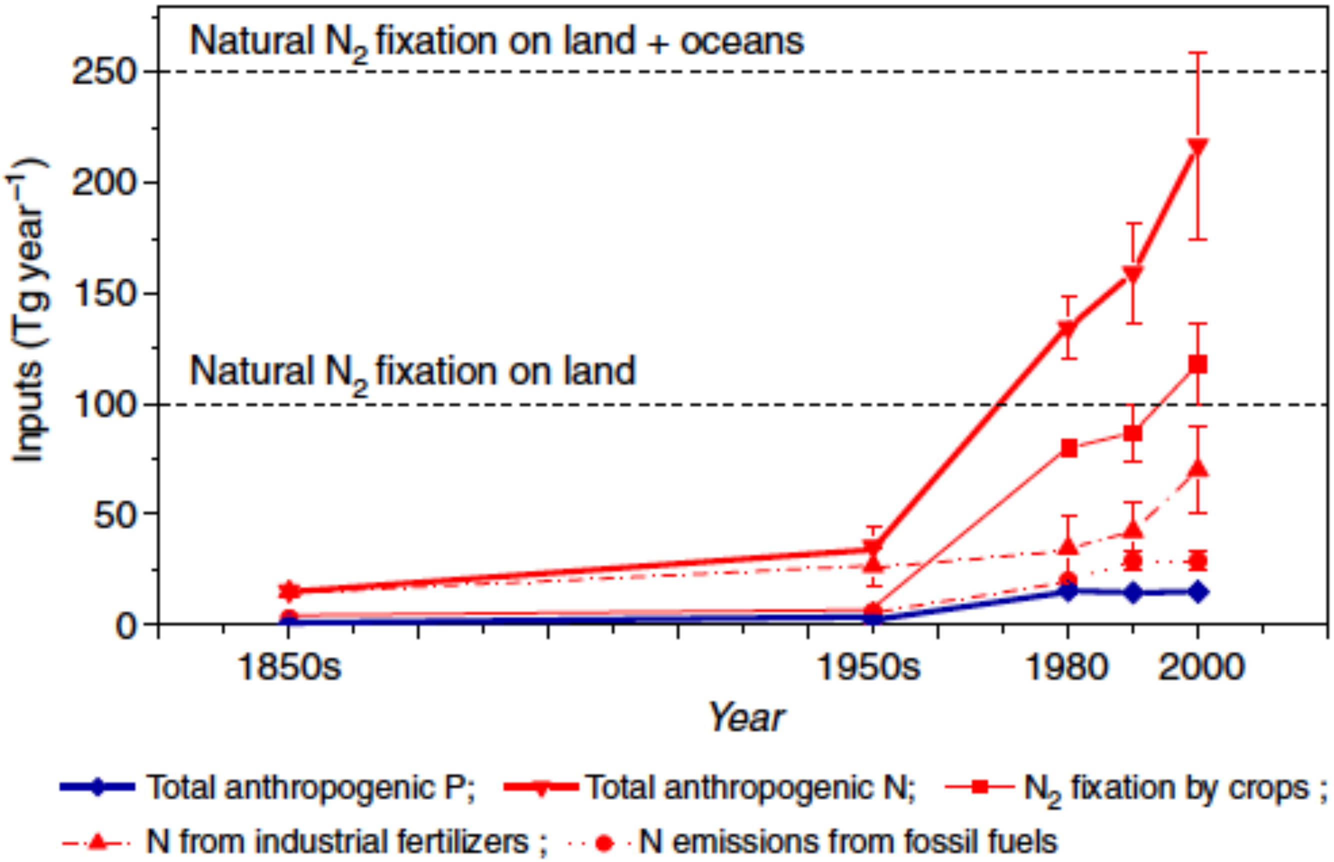


Figure 1 | Anthropogenic N and P inputs to the biosphere. Anthropogenic reactive nitrogen and phosphorus inputs to the biosphere (mean ± s.e., Tg per year) since the industrial revolution (1860). Error bars indicate the range of the data reported[4].

Peñuelas et al. 2013

Human-induced nitrogen–phosphorus imbalances alter natural and managed ecosystems across the globe

- **Change in the stoichiometry of C and N relative to P has no equivalent in Earth's history**.
- A mass balance approach was used to show that **limited P and N availability are likely to jointly reduce future C storage by natural ecosystems** during this century.
- If phosphorus fertilizers cannot be made increasingly accessible - imply an **increase of the nutrient deficit in developing regions.**

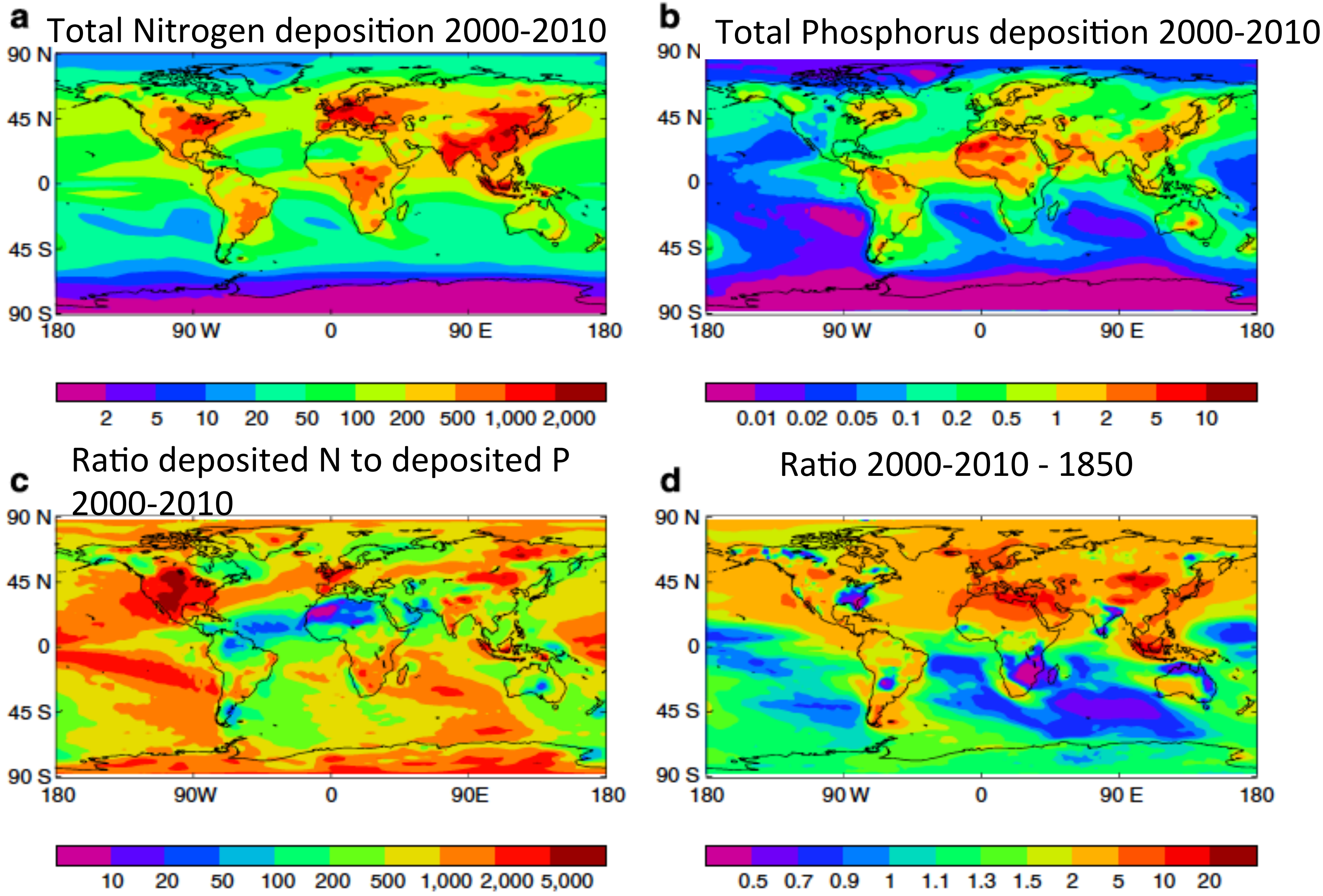


Figure 3 | Increasing N:P ratio of atmospheric depositions. (**a**) Total nitrogen and (**b**) total phosphorus deposition (mg m^{-2} per year), 2000-2010, (**c**) ratio of deposited N to deposited P, for the 2000-2010 decade and (**d**) ratio of the deposited N:P ratio between 2000-2010 decade and 1850. Data are from Lamarque *et al.*[6] and Mahowald *et al.*[3] Only phosphorus as phosphate is considered.

How changing biodiversity affects carbon and nitrogen cycling?

How changing biodiversity affects carbon and nitrogen cycling?

- **Decomposition** = of dead organic matter is a **major determinant of carbon and nutrient cycling in ecosystems**, and of carbon fluxes between the biosphere and the atmosphere.

- Decomposition is **driven by a vast diversity of organisms** that are structured in complex food webs.

How changing biodiversity affects carbon and nitrogen cycling?

- Will biodiversity loss in our forests influence key ecosystem services like the breakdown of organic matter and cycling of nutrients around the planet?

- Handa et al. 2014 - Global litter decomposition experiment

- Fundamental question of how changing biodiversity affects carbon and nitrogen cycling across strongly contrasting ecosystems.

How changing biodiversity affects carbon and nitrogen cycling?

- Key questions:
  - when, where and how biodiversity has a role
  - whether general patterns and mechanisms occur across ecosystems and different functional types of organism.

  - **Field experiments across five terrestrial and aquatic locations,**
  - **Ranging from the subarctic to the tropics**

How changing biodiversity affects carbon and nitrogen cycling?

- Results showed that reducing the functional diversity of decomposer organisms and plant litter types slowed the cycling of litter carbon and nitrogen.
- Loss of consumer and litter functional diversity slows carbon and nitrogen cycling across aquatic and terrestrial ecosystems.

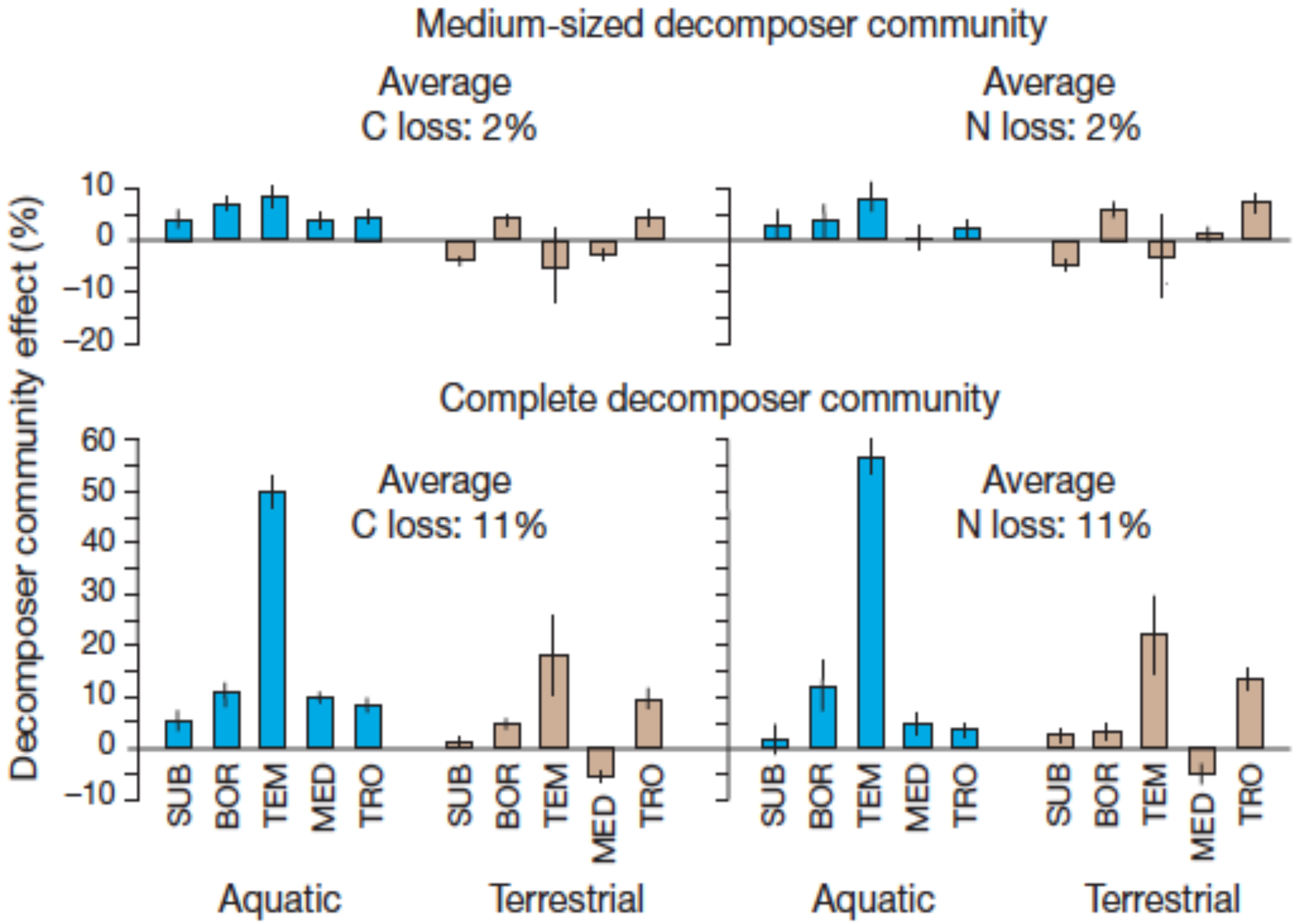


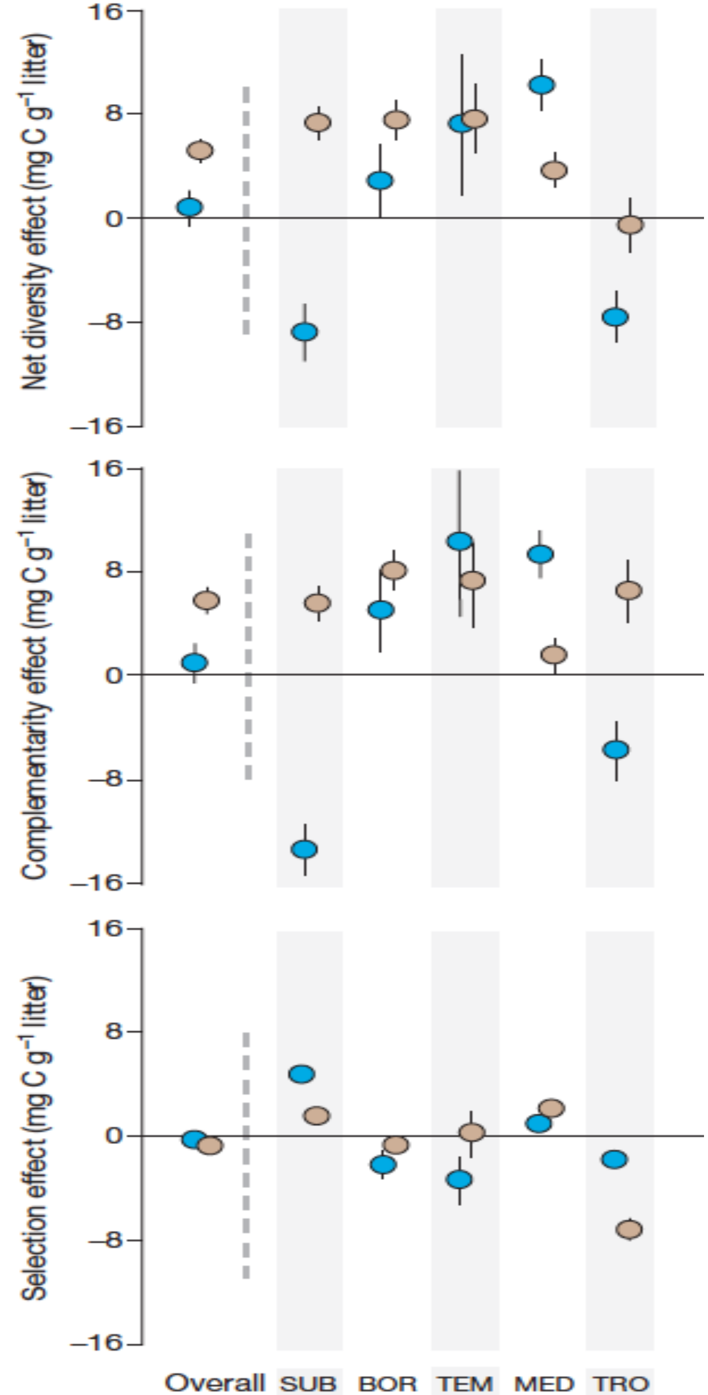
Figure 2 | **Effect of decomposer community completeness on litter C and N loss**. C loss (left) and N loss (right) from all litter treatments (all single species and all mixtures) exposed to medium-sized decomposers (top; percentage difference compared with the smallest mesh size) and the complete decomposer community (bottom; percentage difference compared with the smallest mesh size). The blue and brown bars show mean effects (6s.e.m.) in forest streams and on forest floors, respectively, in the five indicated locations (n545 litter treatments per location per ecosystem type; see Table 1 for statistical analyses).

Net diversity, complementarity and selection effects of plant litter mixtures on C loss.

The net diversity effect is the deviation from the expected mean based on C loss measured from litter consisting of single species.

Blue – forest streams
Brown - forest floors

Locations:
SUB – subarctic
BOR – boreal
TEM – temperate
MED- Mediterranean
TRO - tropical (TRO)



Final remarks

- Many questions remain open about the impacts of N deposition on biodiversity.
- More data on N deposition to different regions of the world and its impacts are needed.
- It is most important to obtain data for regions of the world where N deposition has recently started to increase or is expected to increase in the near future.

Bobbink et al. 2010

Thank you!

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