Evaluating the simulations of global nutrient cycles: available observations and challenges

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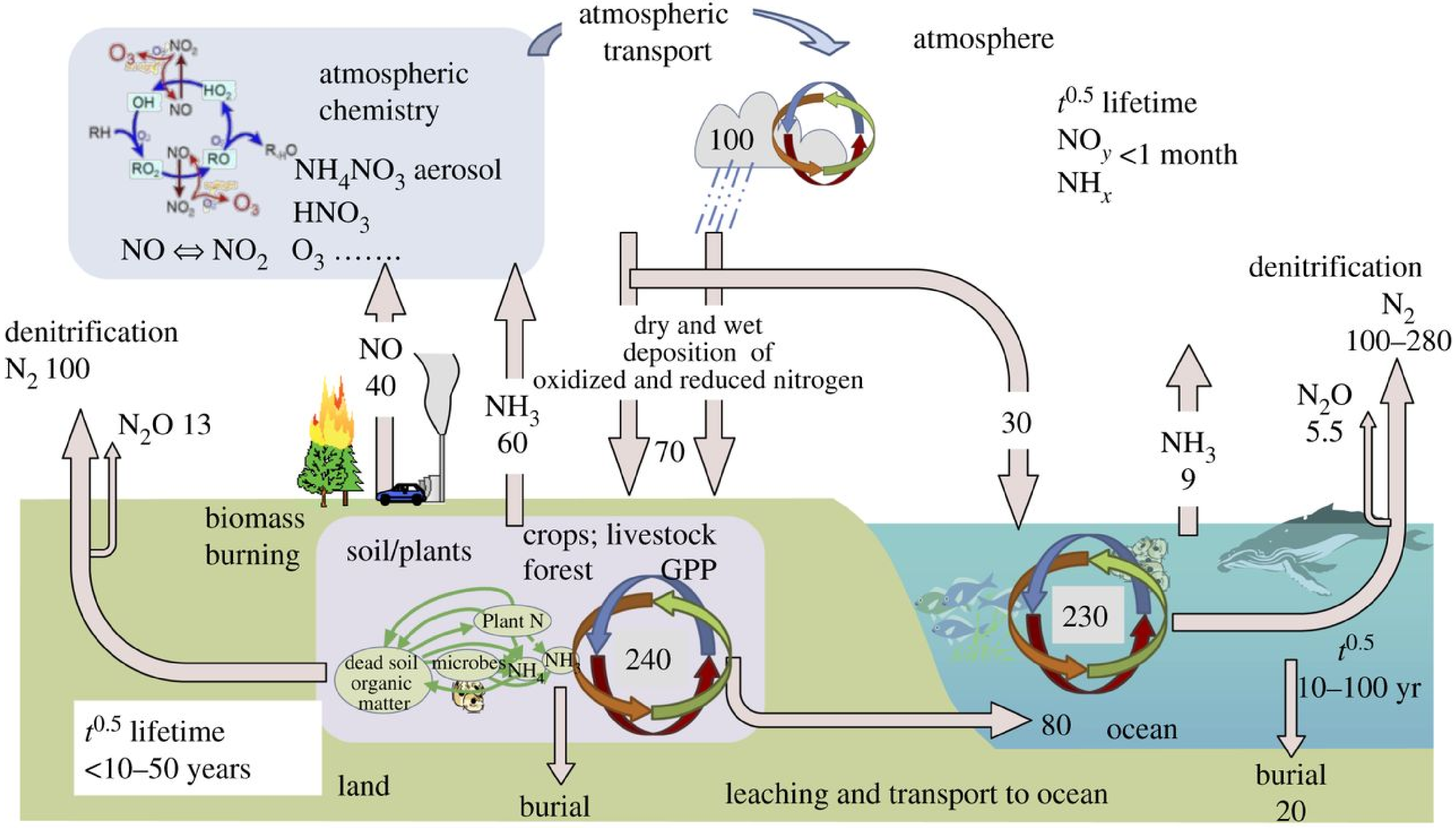
Current status of iLAMB on nutrient

- iLAMB does not include any nutrient data for model benchmarking yet;
- Only one model including N cycle was used for AR5;
- Few global land models with nutrient cycles (<6 for N and 3 for N and P);
- No consistent benchmarking available across all modelling groups on nutrient cycles

Terrestrial N cycle



Major inputs (Tg N /year)

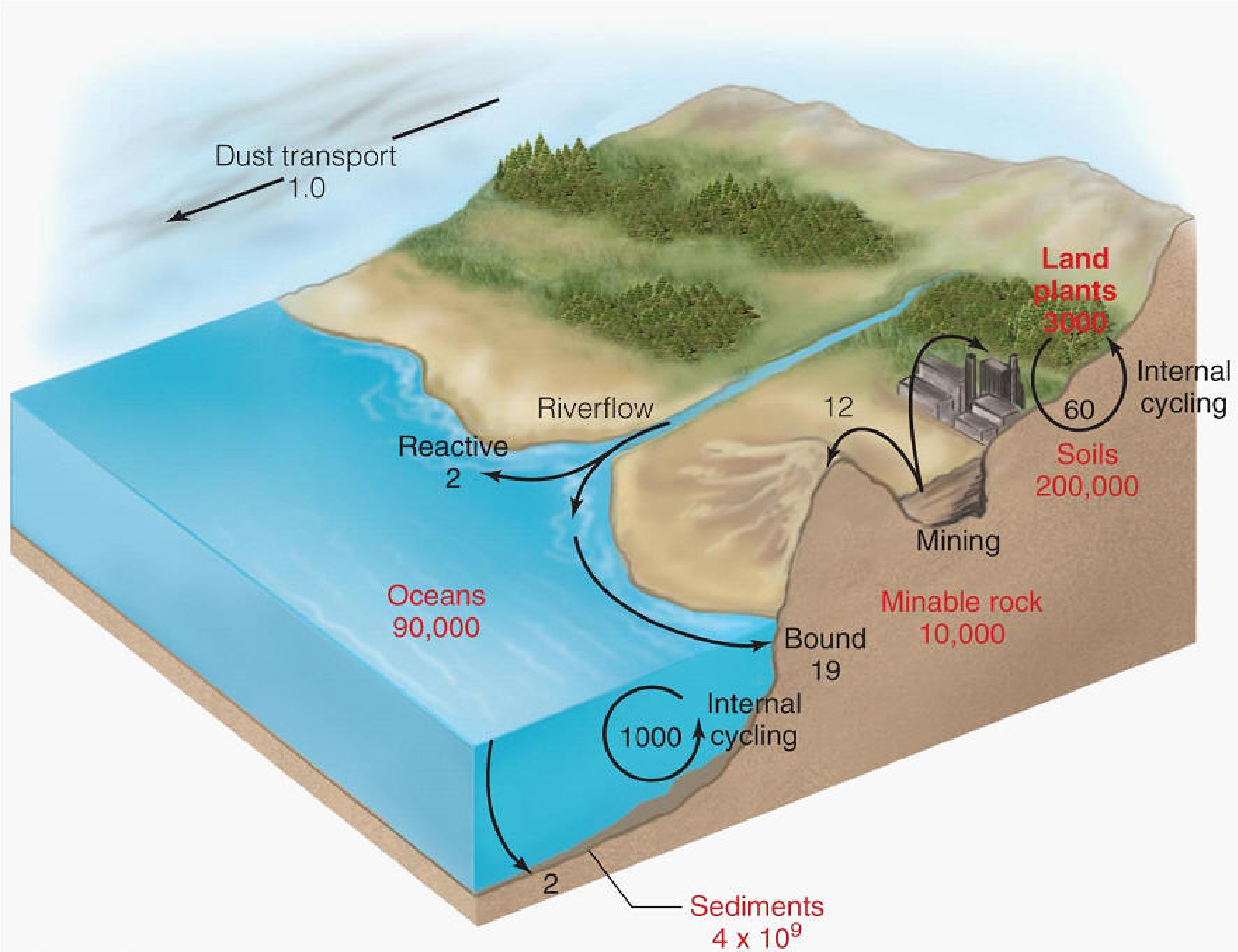
	Preindustrial (1900)	Present (ca 2000)
N deposition	22	63
Lightning	5	5
N fixation	100 (60-150)	120 (60-200)
N weathering	22	22
Fertilizer	1	83
Total	**150**	**293**

N Fate (Tg N/year)

(* calculated as residual)

	Preindustrial (1900)	Present (2000)
Denitrification	65	124
Ammonia emission	10	60
Leaching	30	50
Aerial transport to ocean	6	48
Soil accumulation	27*	11*
Total	**150**	**293**

Global phosphorus cycle



Input (Tg P/yr):

Deposition: 2.7
Weathering:1.1
Fertilizer:14

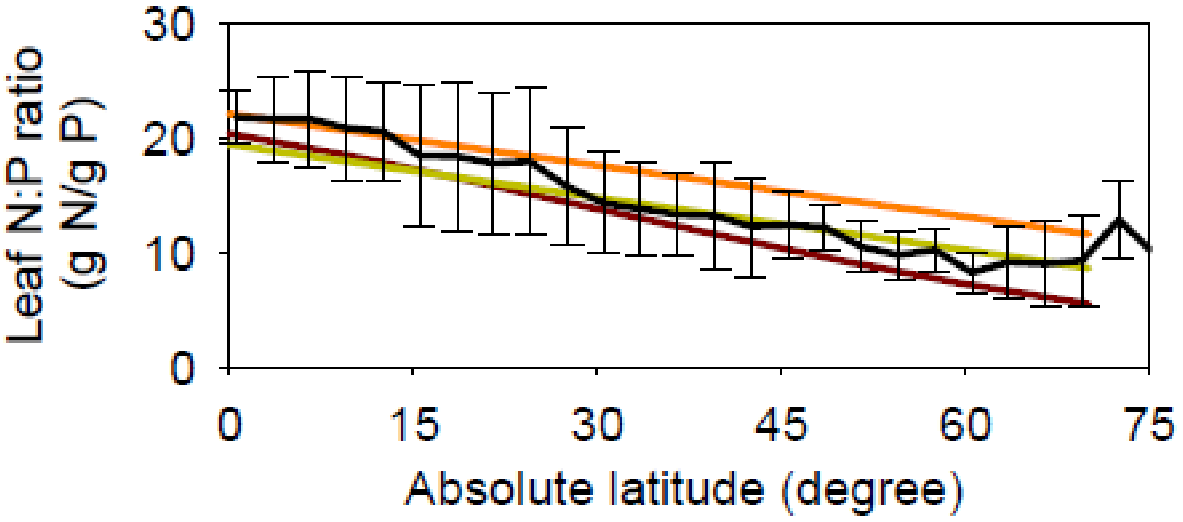
Fate:
Leaching: >2.0 (18-30)
Fire+wind:1.8
Soil: 2

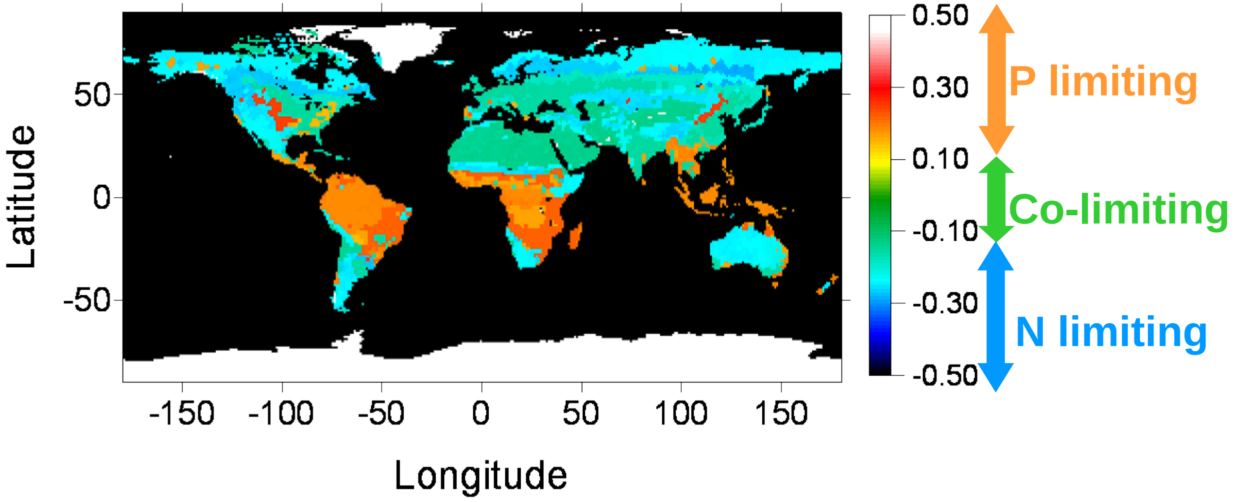
Key datasets for evaluating nutrient cycles

In addition to dataset used for evaluating carbon cycles

- Latitudinal variations of leaf C:N:P ratios
- Soil N and P pool sizes, soil $\delta^{15}N$
- Global nutrient fluxes from land to ocean
- Long term (>10 years) field experiments

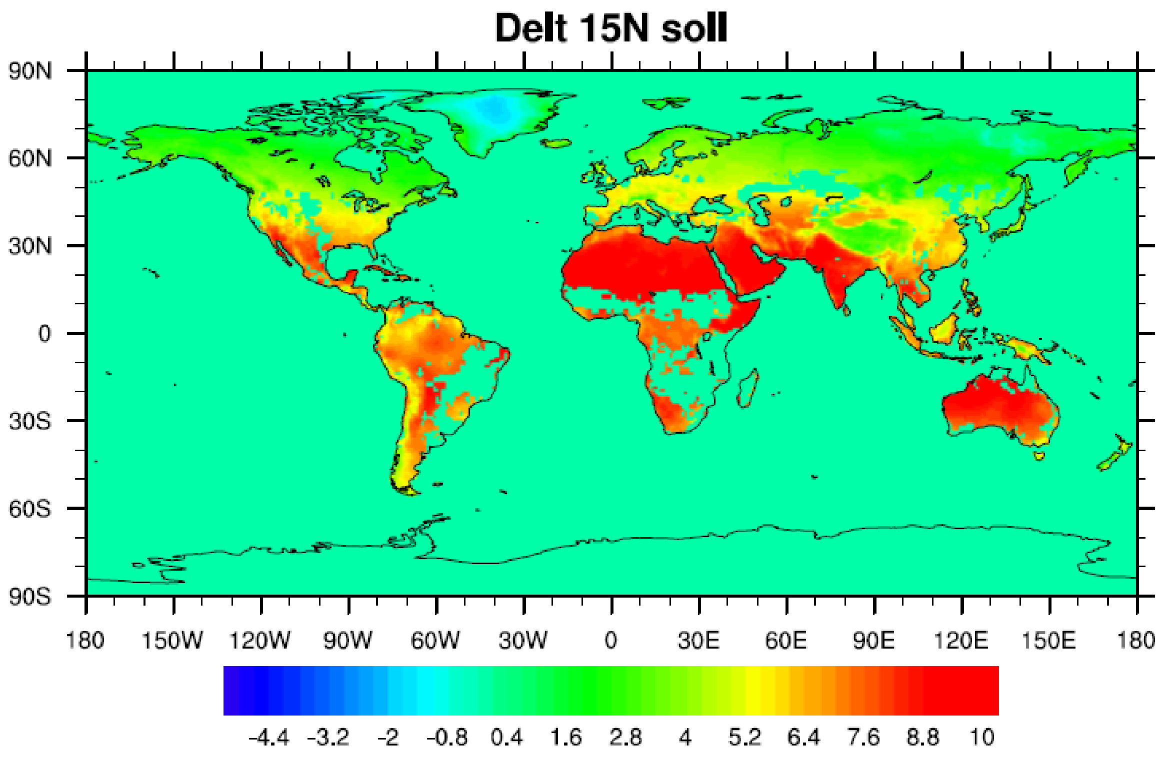
Latitudinal variations: evidence of the broad geographic pattern of nutrient limitation

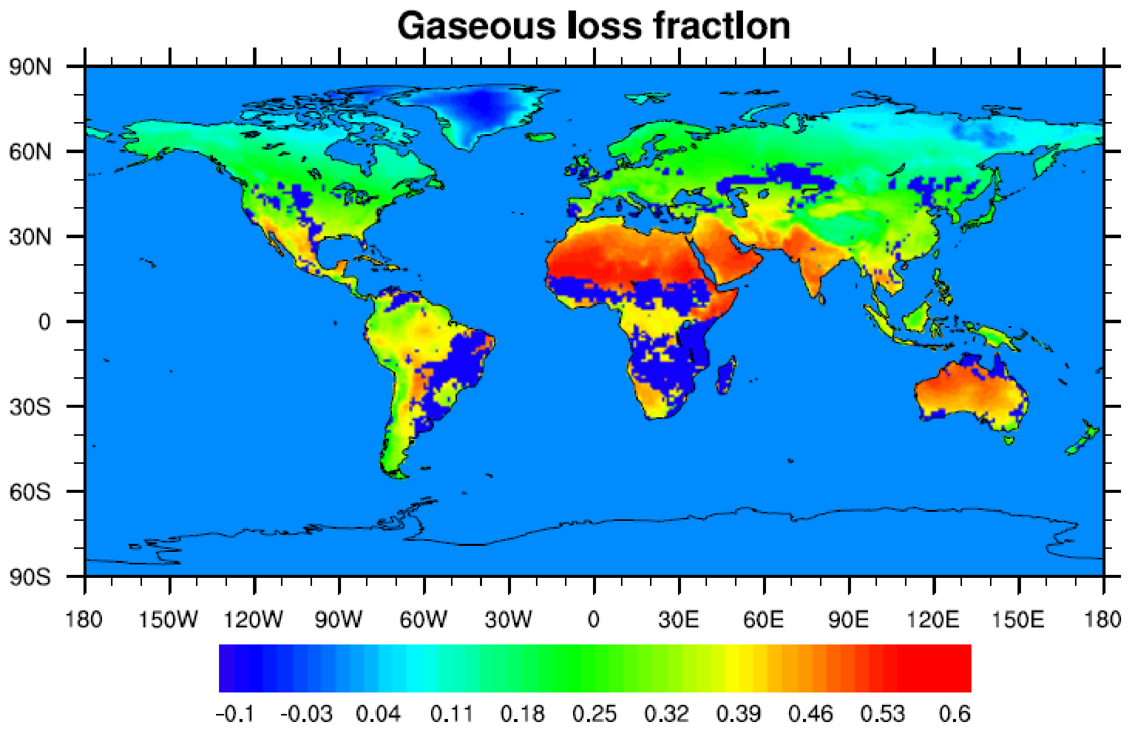




Wang, Law and Pak et al. 2010, Biogeosciences

Soil $\delta^{15}N$ data and gaseous loss





Source: Houlton, Marklein and Bai 2015, Nature Climate Change

A nitrogen isotope (^{15}N) constraint on N effluxes (Houlton, Bai and Alison 2015)

Basic theory:

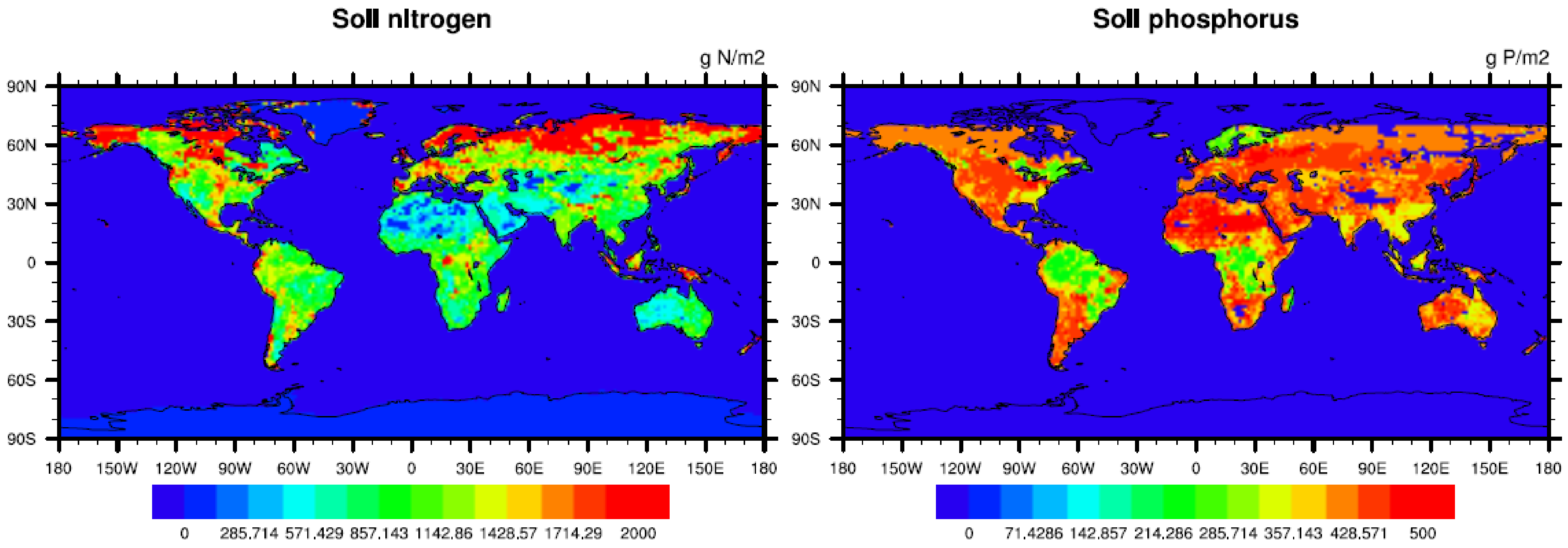
$$f_{gas} + f_{NH3} + f_L = 1$$

$$\delta^{15}N_{soil} = \delta^{15}N_{input} + \varepsilon_{gas} f_{gas} + \varepsilon_{NH3} f_{NH3} + \varepsilon_L f_L$$

For unmanaged land with negligible NH_3 emissions

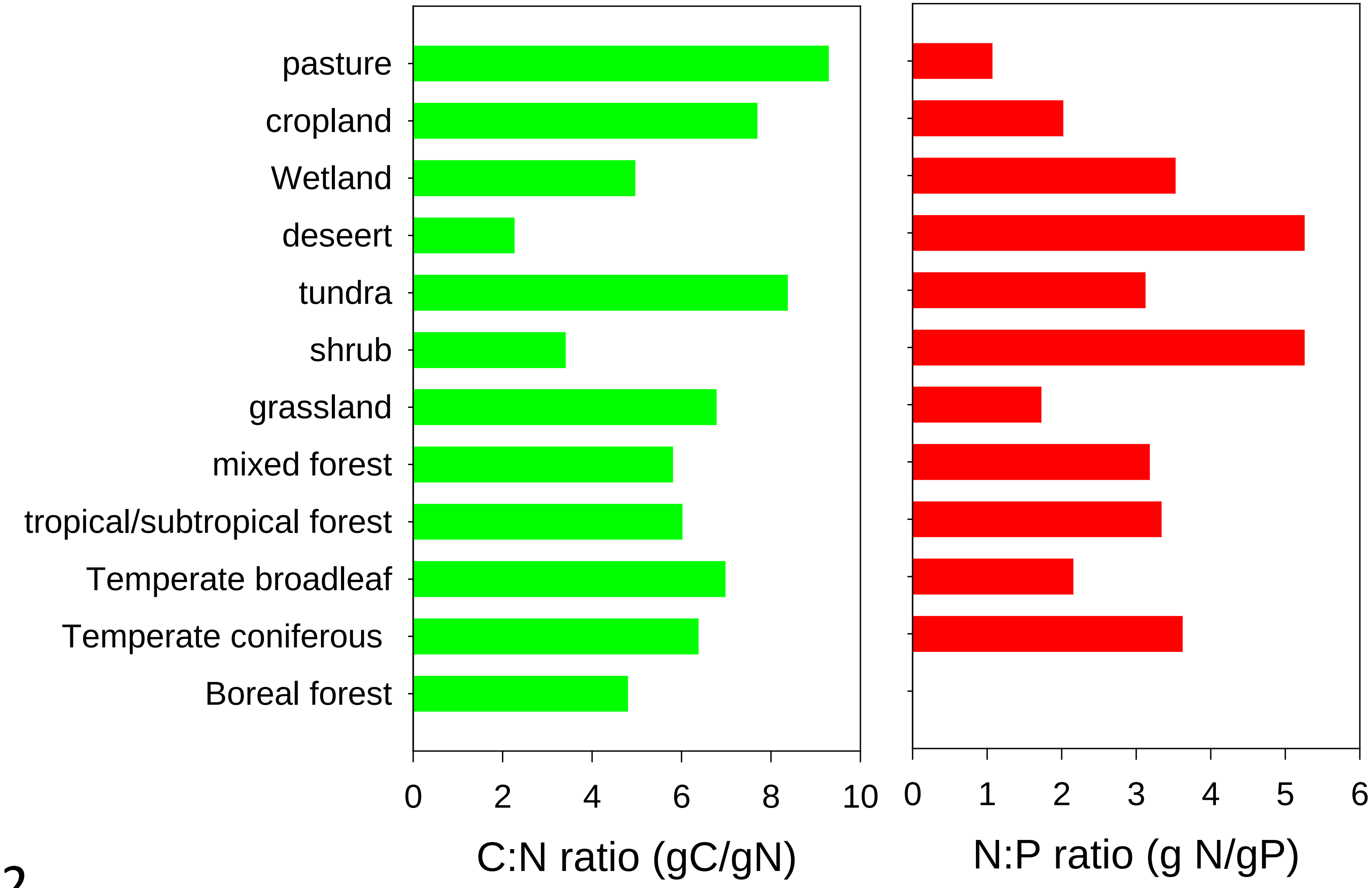
$$f_{gas} = \frac{\delta^{15}N_{soil} - \delta^{15}N_{input} - \varepsilon_L}{\varepsilon_{gas} - \varepsilon_L}$$

Soil N and P data



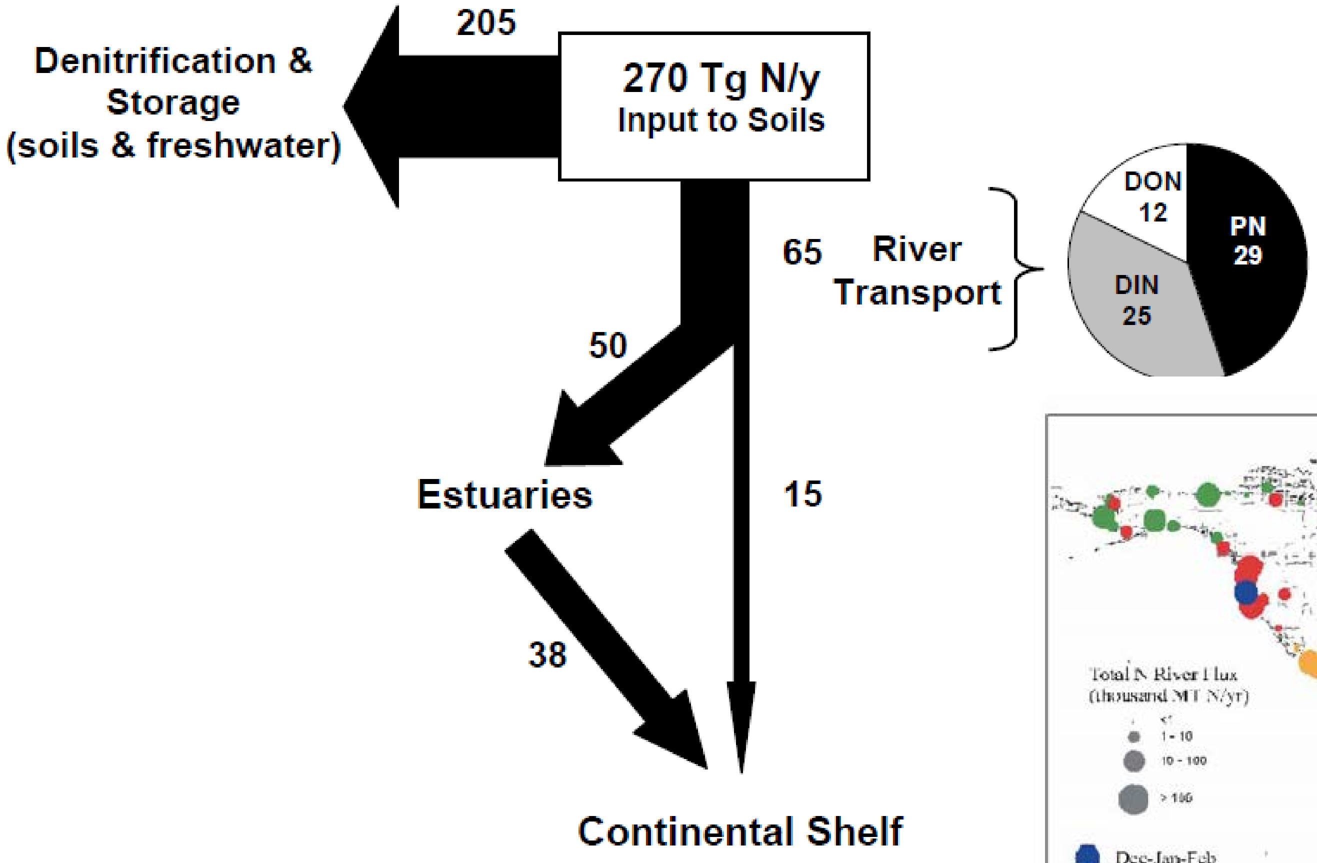
Source: Batjes (2009); Yang et al. (2013)

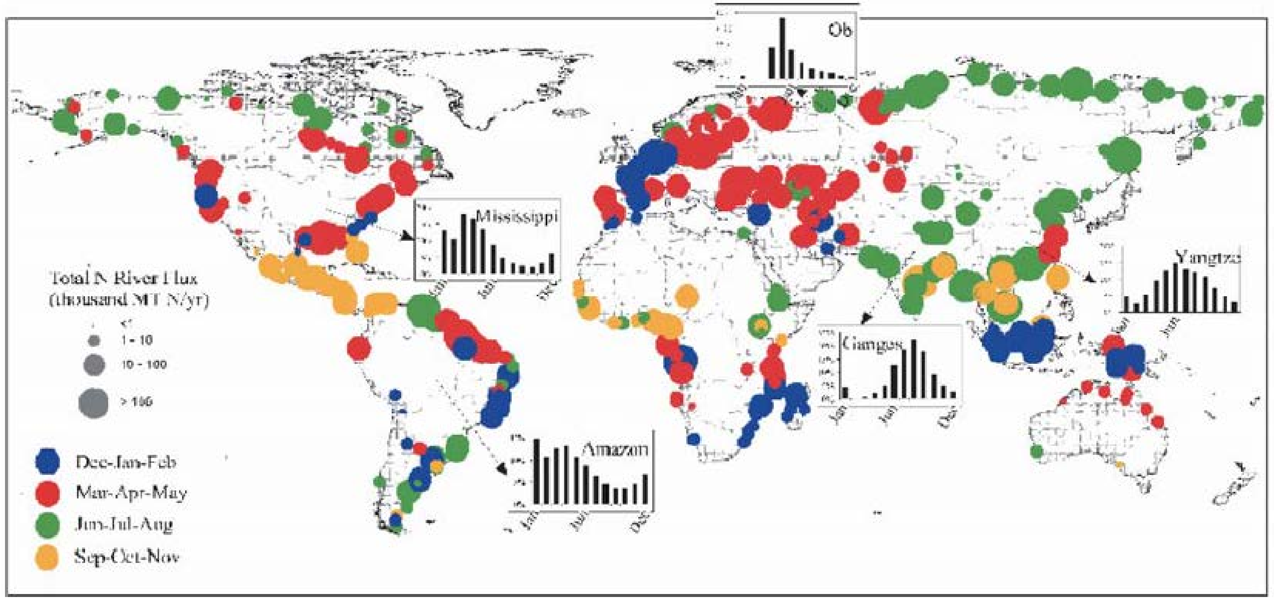
Microbial C:N:P



Source: Xu et al. 2012

Loss of N from land





Source: Seitzinger et al

N and P losses from land (Tg N or P/year)

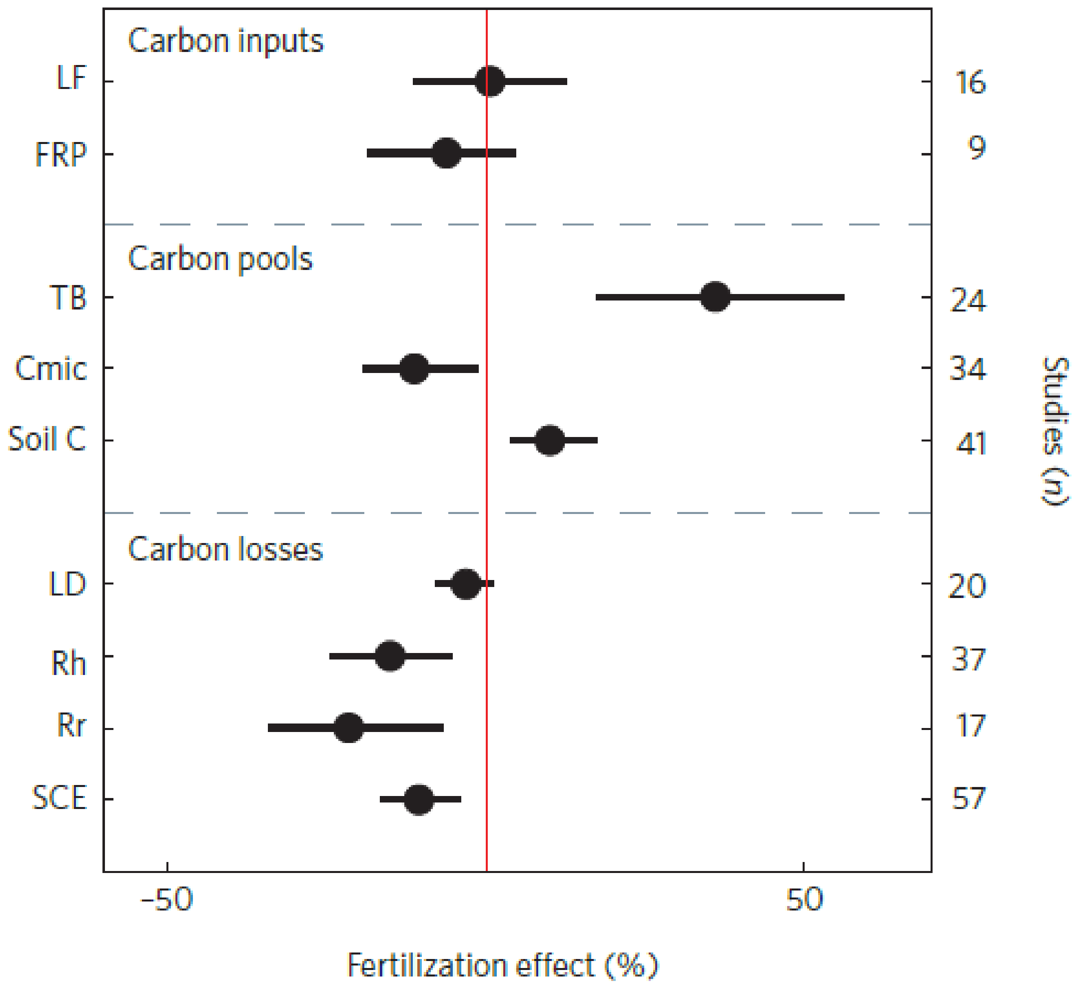
Species	**N**	**P**
Dissolved inorganic	18.9	1.4
Dissolved organic	10.8	0.6
Particulate matter	13.5	6.6
Total	**43.2**	**8.6**

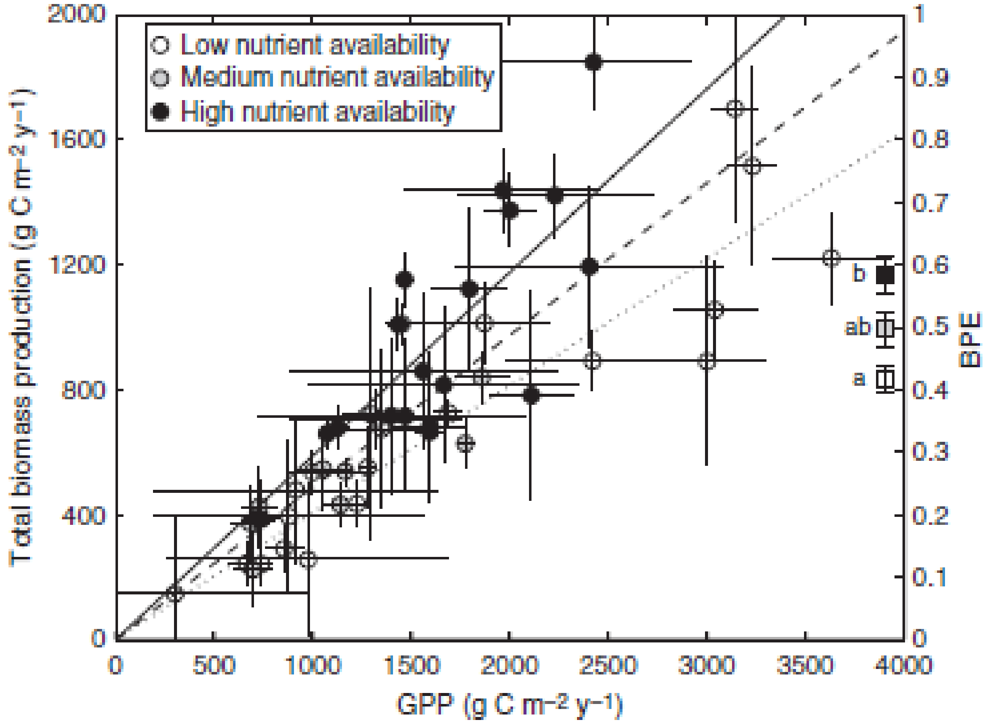
Source: Kroeze, Bouwman and Seitzinger 2012

Long term fertilizing experiments with some detailed process data (>10 years)

- Tropical forest:
  - Hawaii chronosequence (*different soil substrates*, **evidence for Walker and Syer's hypothesis**)
  - Dinghushan (*successional gradient*, **evidence for limiting nutrient shift**)
  - Gigante experiment (1998-2007) (**no changes in soil carbon and N after decades of N, P or K addition**)
- Temperate forest: Harvard forest (**fertilizer addition reduced microbial biomass**)
- Boreal forest: Flakliden (*interactions with high CO_2 and warming*, **no growth response unless N is added**)

Key results (responses to N addition)





Source: Janssens et al. 2010; Vicca et al. (2012)

Challenges in constraining nutrient cycles

- Large uncertainties in the inputs, and some inputs are missing
- Losses from dissolved organic and particulate matters are not represented in most models, a significant issue for P
- No observation-based global data product of mineralization, uptake; denitrification loss
- Large variations of fluxes and pool sizes in time and space

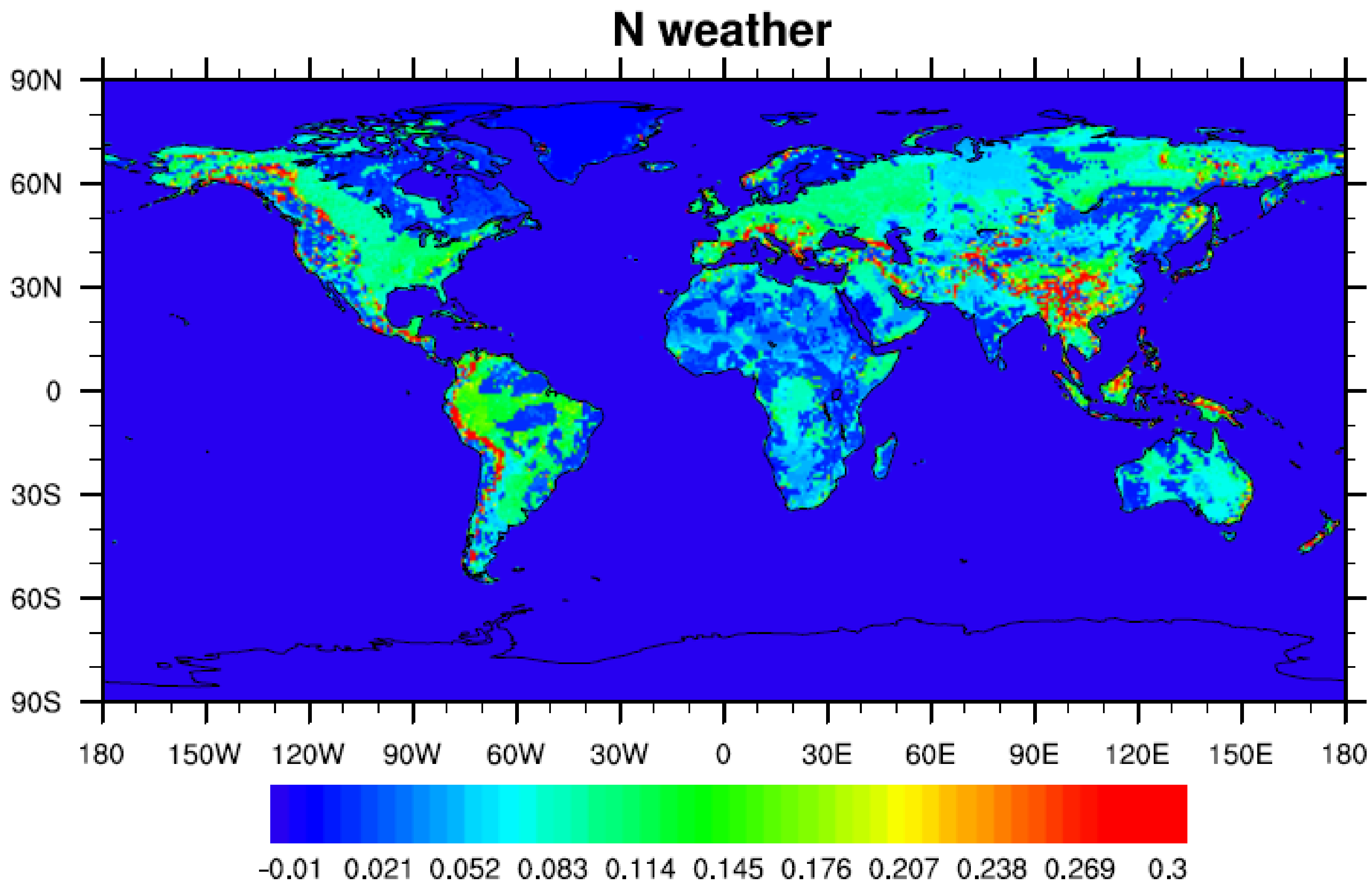
Large uncertainties of inputs: N fixation

For the mass weighted globally mean $\delta^{15}N_{soil}$ is 5.8 ‰, $\delta^{15}N_{input}$ =-1‰; ε_{gas}=-15‰, ε_{l} =0‰

We have: f_{gas}=0.45

Given N_{dep}=22 Tg N/year in 1900
If N_{gas} = 65 Tg N/year, N_{fix} =42 Tg N/year
If N_{l} =35 Tg N/year, N_{fix}= 122 Tg N/year

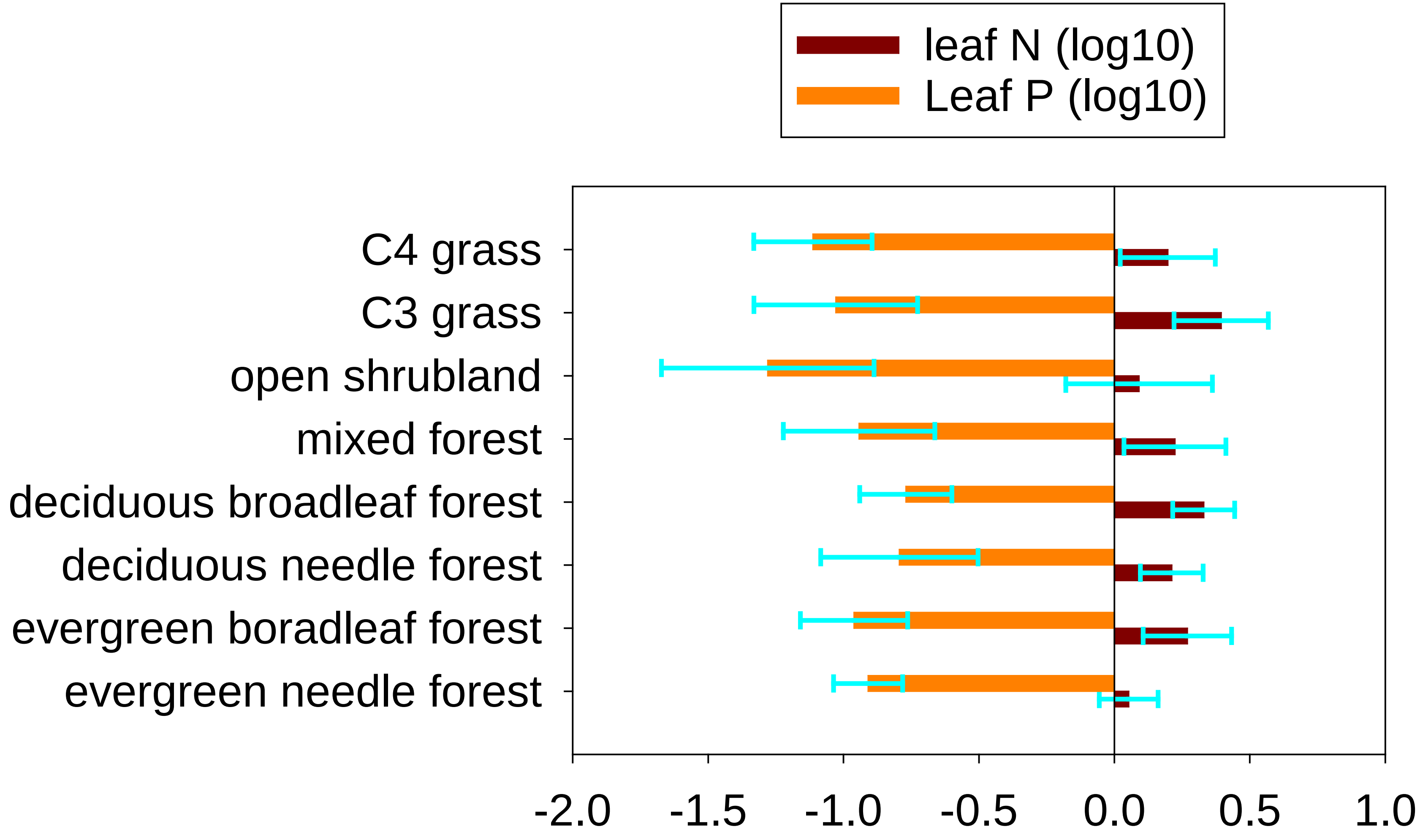
Other inputs: N-rock weathering (g N m^{-2} yr^{-1})



Globally rock-weathering of N-rich rock provides 21 Tg N/year to land ecosystems!

Source: Morford, Houlton and Dahlgren in press

Large intra-PFT variations of C:N:P of plant tissues



Source: Ian Wright and Peter Reich

Nutrient-data for iLAMB

- Identify key experimental dataset for model evaluation
- Add nutrient data to iLAMB
- Organize nutrient MIPs

Two international workshops in 2016

- 23-25 May 2016, Townsend, USA, *P model-measurement workshop*
- 15-17 June 2016, Yangling, China, *Nutrient limitation on land: how accurate are our global land models*?