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REVIEW AND SYNTEHSIS

A review of nitrogen enrichment effects on three biogenic GHGs: the CO_2 sink may be largely offset by stimulated N_2O and CH_4 emission

Environmental Media
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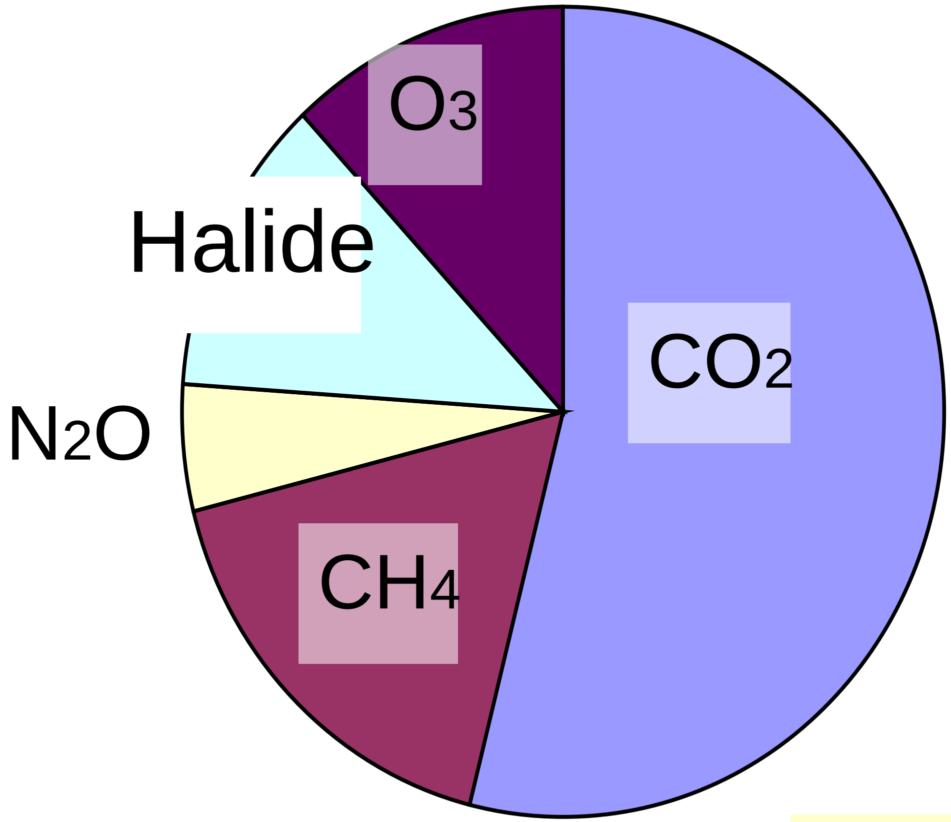
Motivation

I am interested in how the changing environment influences our world and life.

We all know that the world is changing rapidly due to the rapid development. Human now has the power to change the nature; but on the other hand, this "haughtiness" is also regarded as a harm.



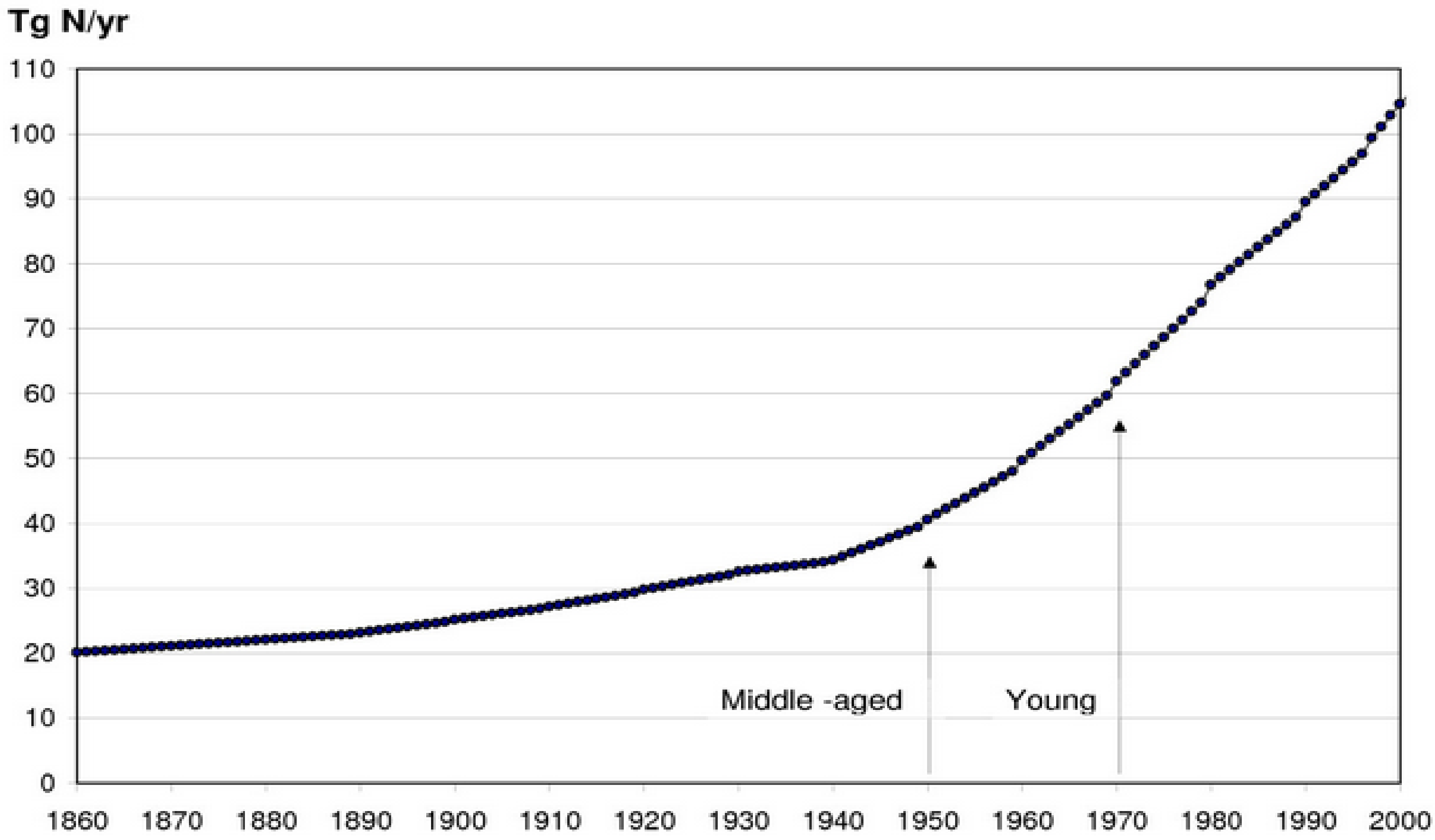
CH_4 is produced under unaerobic as well as aerobic condition !

Radiative forcing of CH_4 is about 25 times of CO_2 per mass bases

Contribution of many Gases for inducing global warming

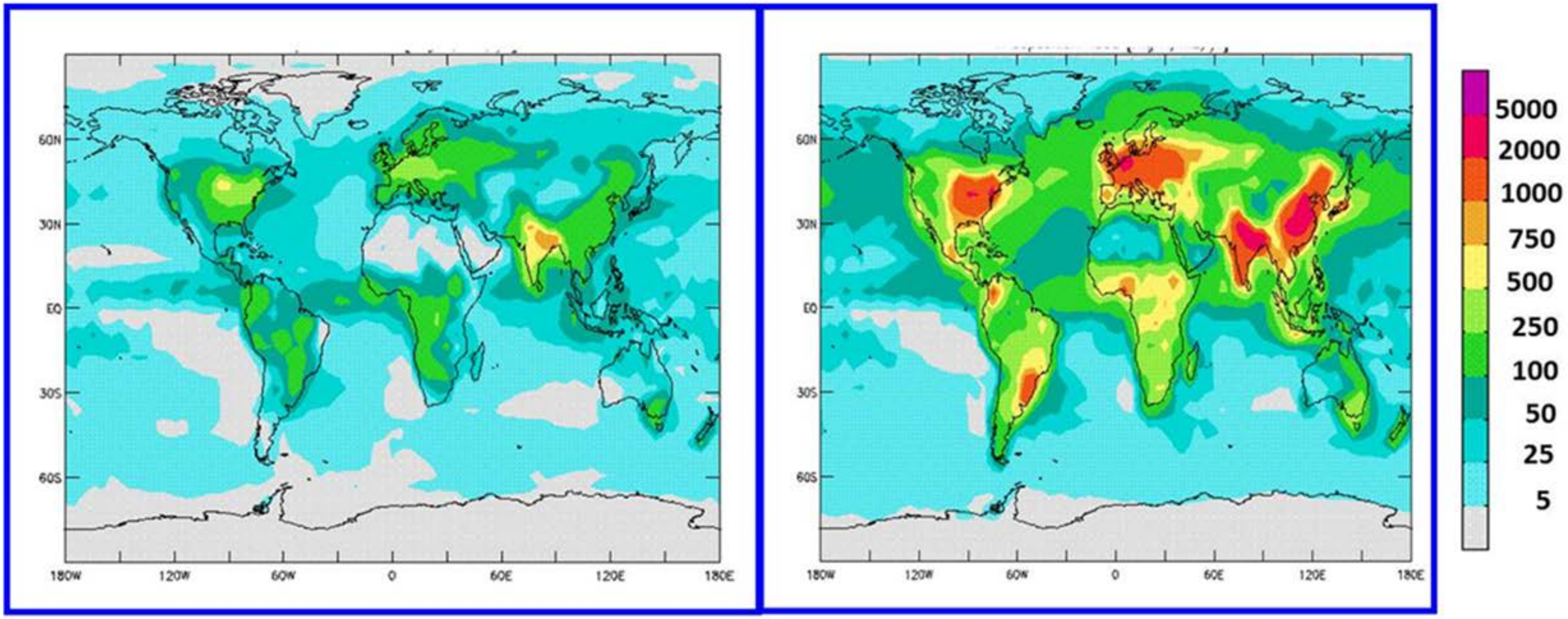
BACKGROUND

annual input of anthropogenic reactive nitrogen



(LeBauer, D.S. & Treseder, K.K. 2008)

Nitrogen deposition



1860 1993

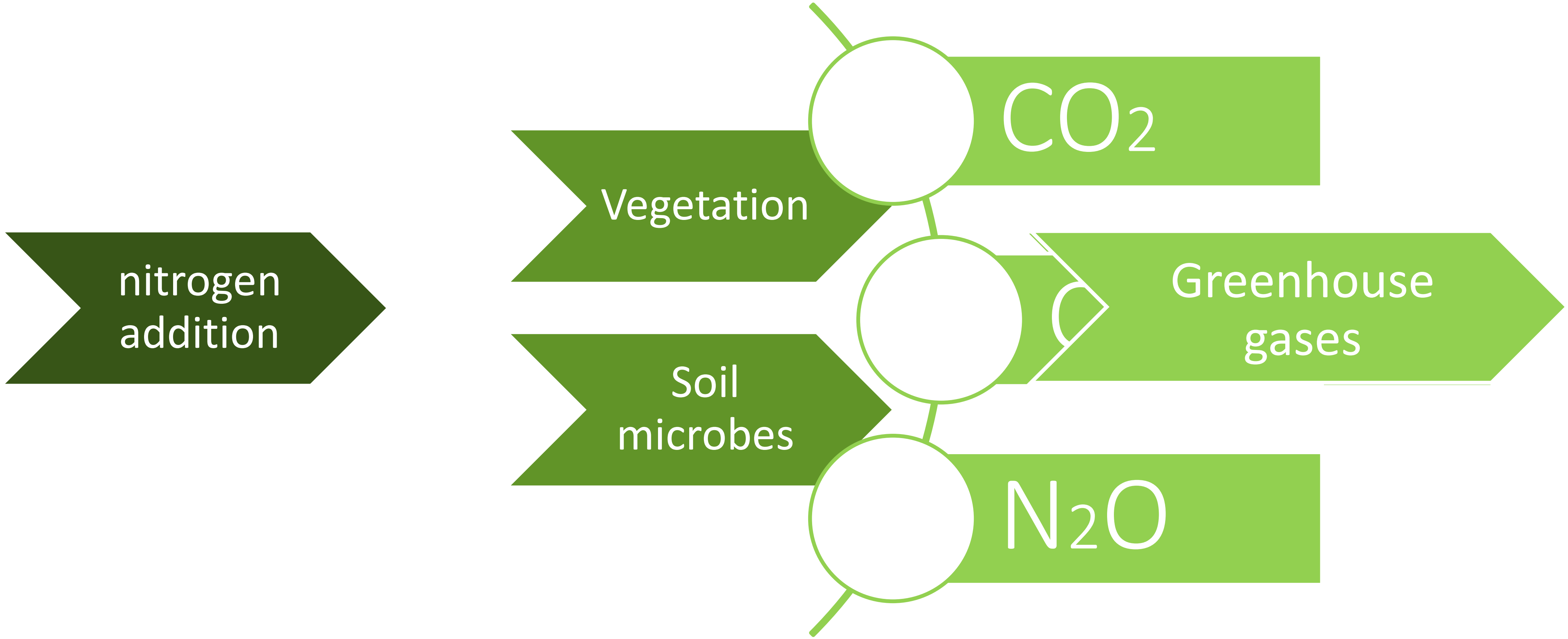
(Reich, P.B, et al. 2008)

Global warming

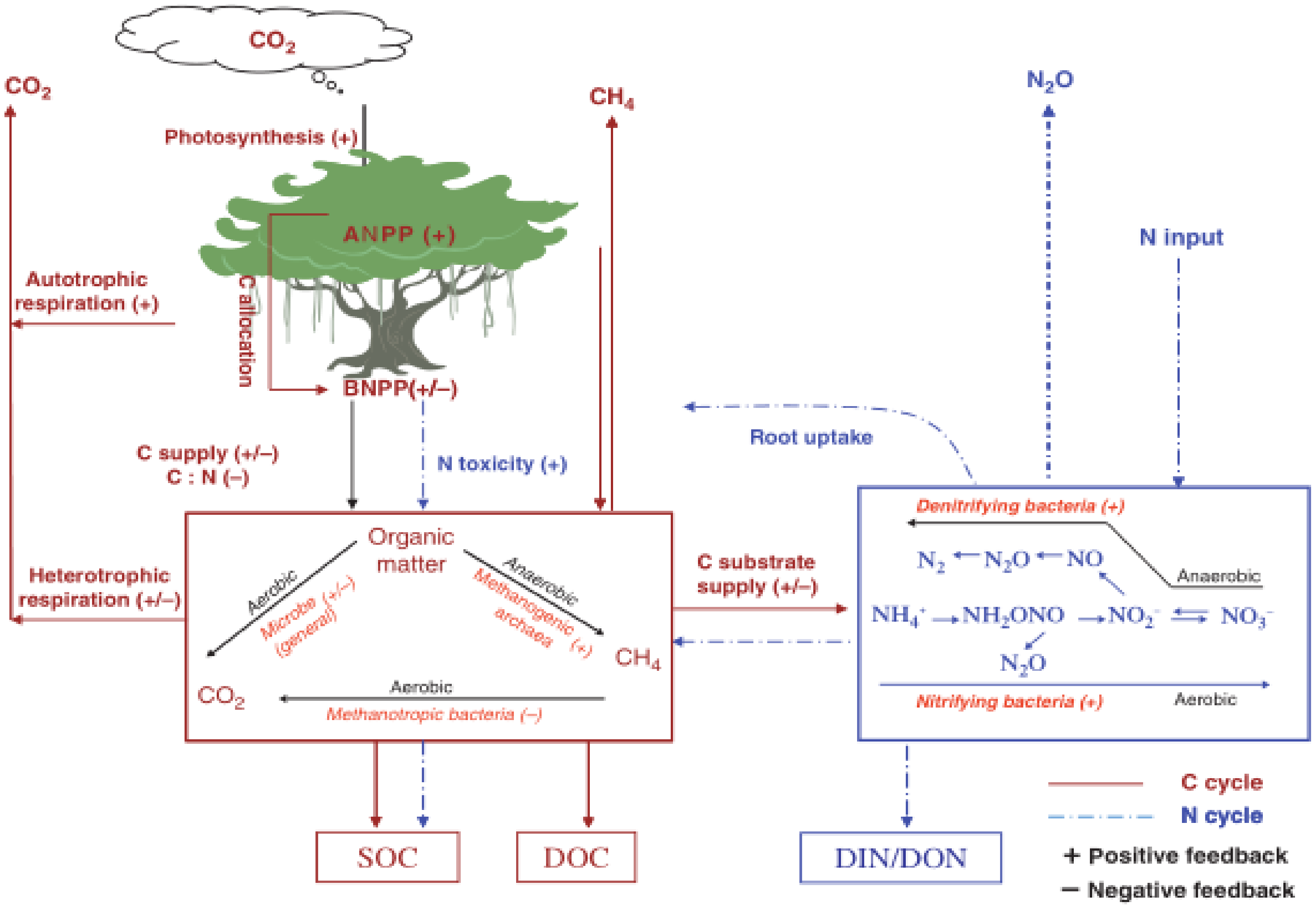
INTRODUCTION

How can nitrogen addition affect the biogenic greenhouse gas budget ?

INTRODUCTION



MECHANISM



ANPP—aboveground net primary productivity

BNPP—belowground net primary productivity

SOC—soil organic carbon

DOC—dissolved organic carbon

DIN—dissolved inorganic nitrogen

DON—dissolved organic nitrogen

Nitrogen cycle ⟷ Carbon cycle

Related by :

1) photosynthesis
2) plant respiration
3) C allocation
4) microbial decomposition

MECHANISM

- CO_2

nitrogen addition

↗ Plant growth → C sequestration

→ Maintenance respiration

Refers to the energy needed to maintain the organism in healthy living state

(Distinguished from “growth respiration”)

↘ Litter decompose faster

(with higher N)

MECHANISM

Produce their own food from the substances available in their surroundings

↑

Autotrophic respiration

Increased leaf nitrogen content (under elevated N) → Higher carbon loss → CO_2

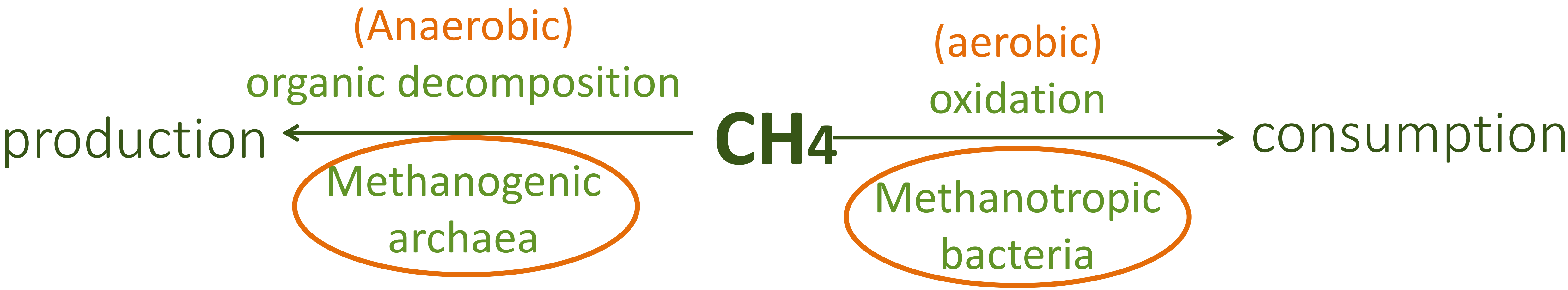
Heterotrophic respiration

↓

cannot synthesize their own food and rely on other organisms for nutrition

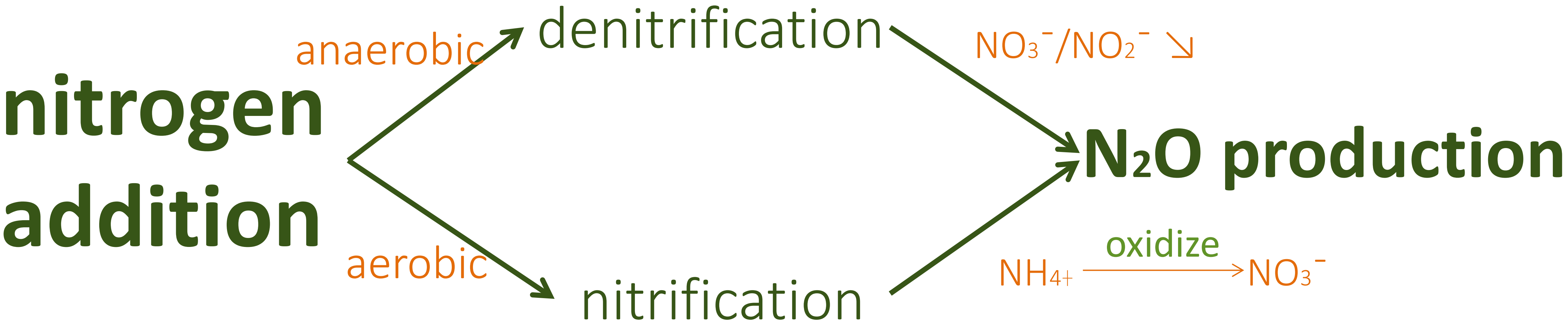
MECHANISM

- CH_4



MECHANISM

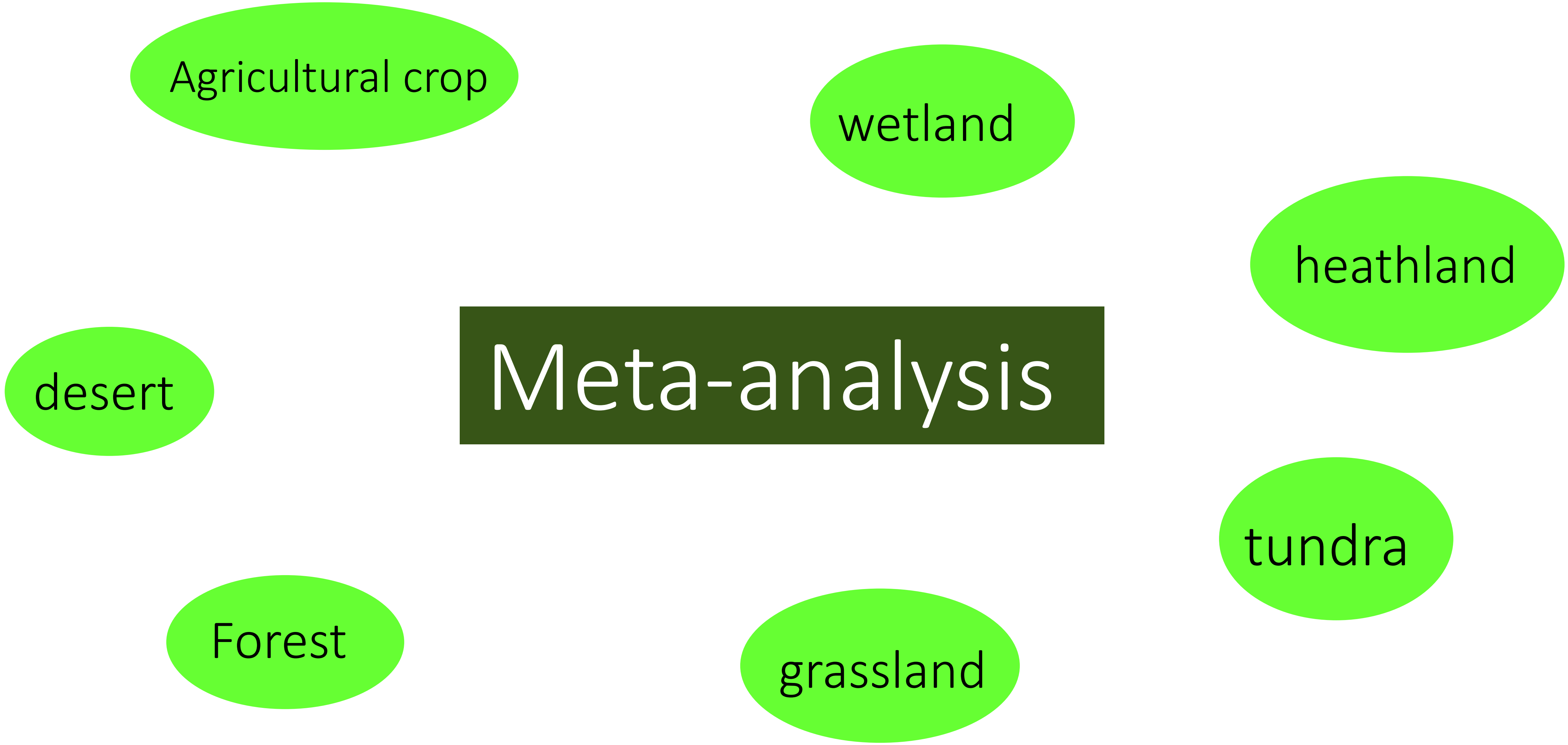
- N_2O



DATA SELECTION

Consider TOTAL ecosystem flux

Consumption ⟷ Production


Agricultural crop
wetland
heathland
desert
Meta-analysis
tundra
Forest
grassland

DATA SELECTION

- observation

109 publications

↓

313 observations

1) Ecosystem type;
2) The level of N loading;
3) Chemical form of N addition;
4) Experimental condition

DATA SELECTION

- parameters
  - **NEE**——net ecosystem CO_2 exchange (non-forest natural ecosystems)
  - **EC** ——ecosystem C content (forest ecosystems)
  - **SOC**——soil organic carbon (agricultural ecosystems)
  - **CH_4 emission**
  - **CH_4 uptake**
  - **N_2O emission**

META-ANALYSIS METHODS

VARIABLES:

- Response ratio
- Variance
- Heterogeneity
- Emission/uptake factor (F)
- Geq

META-ANALYSIS

- Response ratio

$$r = \bar{X}_T / \bar{X}_c$$

Treatment mean

Control mean

Estimate effect size for each individual observation

META-ANALYSIS

- variance

Control standard deviation

Treatment standard deviation

$$v = \frac{(SD_c)^2}{n_c \bar{X}_c} + \frac{(SD_T)^2}{n_T \bar{X}_T}.$$

Estimate the fluctuation

Control replication number

Control mean

Treatment replication number

Treatment mean

META-ANALYSIS

- Heterogeneity

$$Q_t = Q_b \quad Q_b$$

Total heterogeneity among group

Within group heterogeneity

Between group heterogeneity

Estimate whether response ratios differ for the levels of this group

EMISSION/UPTAKE FACTOR

- Emission/uptake factor (F)

Annual flux of GHG from fertilized treatment

Annual flux of GHG from control

Annual nitrogen input

$$F = (G_N - G_C)/N,$$

Changes in GHG flux on global scale (Geq)

Estimated for variables which were significantly influenced by nitrogen addition

GLOBAL BIOGENIC GHG BUDGET ESTIMATION

- Changes in GHG flux on global scale (Geq)

Level of nitrogen addition

Global surface area of the ecosystem

Weight conversion factor

$$Geq = L \times F \times S \times E \times GWP$$

global warming potential

RESULTS

1) C balance
2) CH_4 flux
3) N_2O flux
4) Global greenhouse gas budget

- # 1. C balance

Effect of N addition on NEE, EC and SOC

Response variable	n	R	95% CI
NEE of non-forest natural ecosystem			
Overall	16	0.90	0.73–1.12
Grassland	7	0.95	0.64–1.40
Wetland	6	0.84	0.53–1.32
Tundra	3	0.91	0.35–2.38
EC of forest ecosystem			
Overall	17	1.06	1.01–1.12
Coniferous	8	1.07	1.00–1.17
Deciduous	9	1.04	0.97–1.11
SOC of agriculture ecosystem			
Overall	18	1.02	1.00–1.05

n, no. observations; *R*, the mean response ratio; 95% CI, 95% confident intervals.

Table 2

N addition

non-forest natural—— NEE ： no significant effect

forest—— EC ： increase **6%**

Coniferous forests shows higher response than deciduous forests

Agricultural—— SOC ： increase **2%**

2. CH_4 flux

effects of nitrogen addition on biogenic methane emission

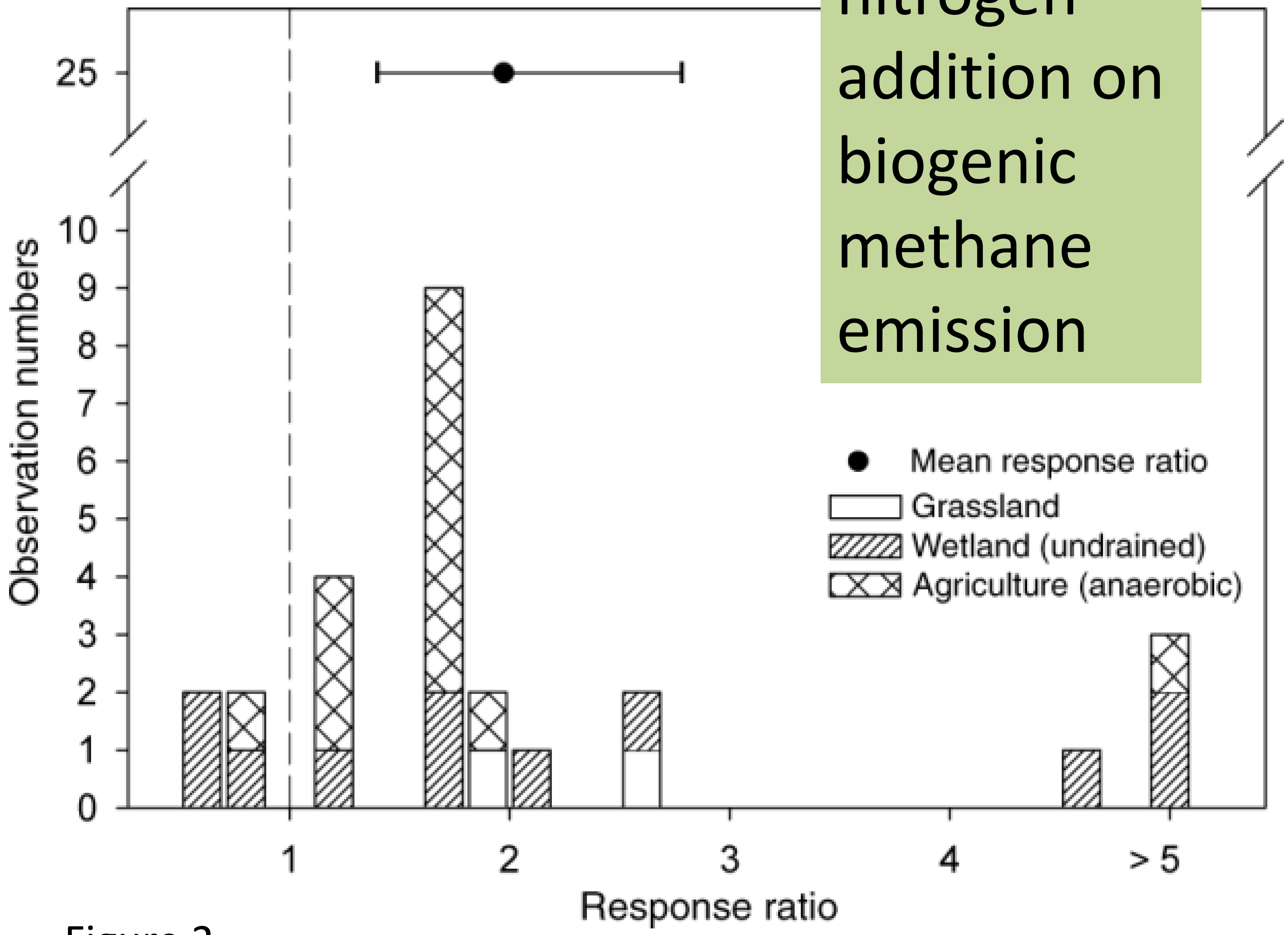


Figure 2

N addition

increase CH_4 emission

95%

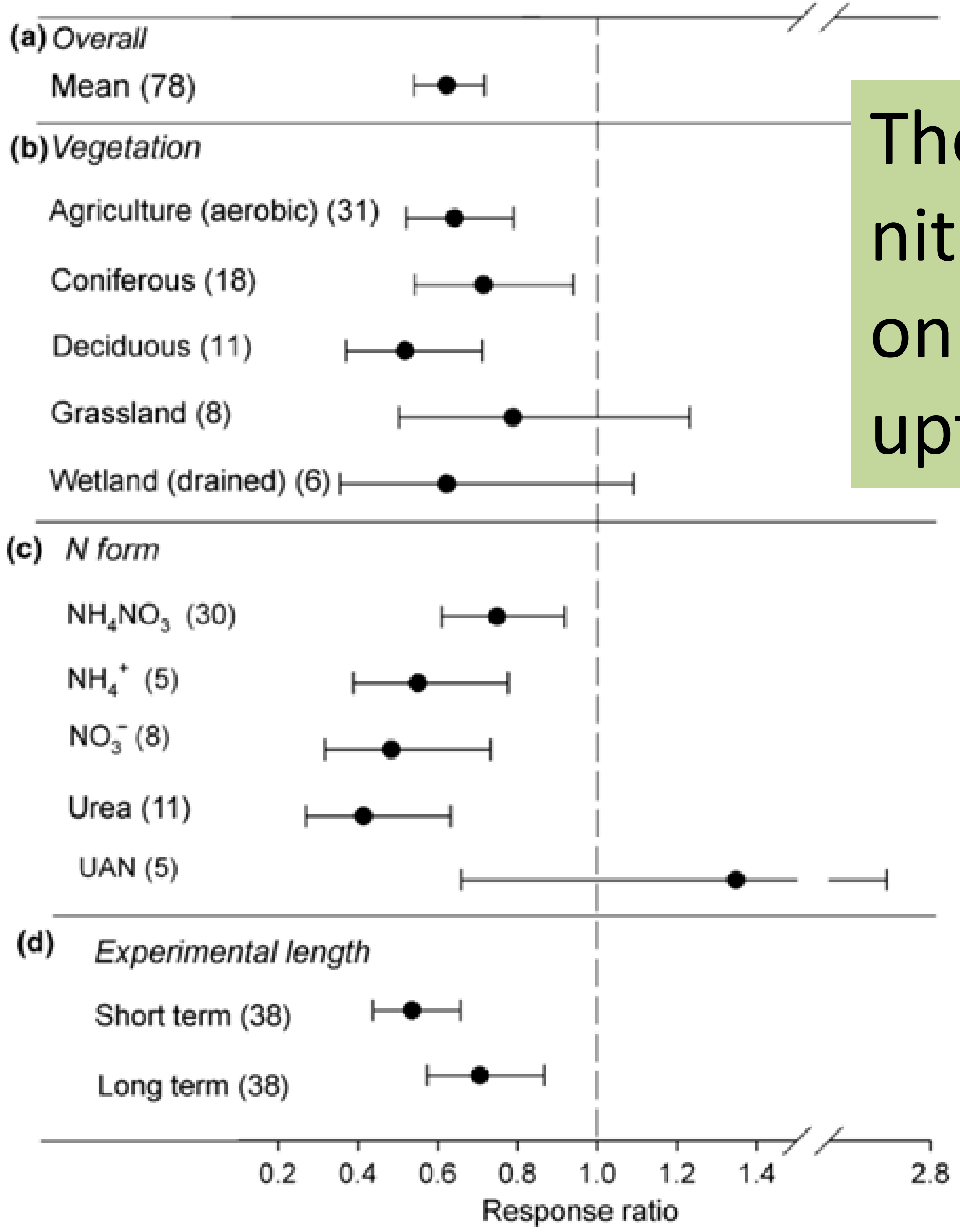


Figure 3

The effect of nitrogen addition on methane uptake

N addition

reduce CH_4 uptake

38%

3. N_2O flux

N addition

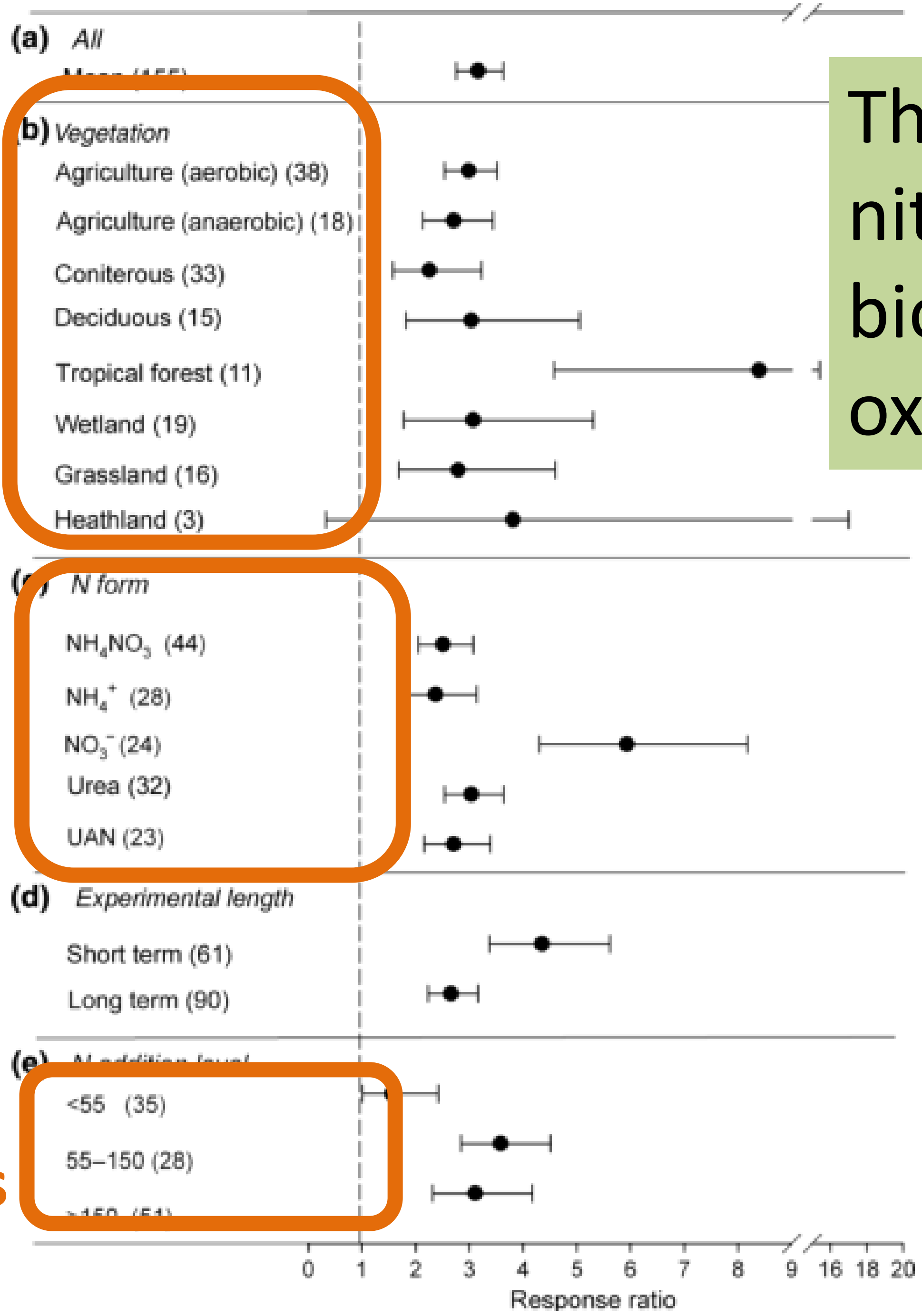
Types of ecosystems

Forms of nitrogen

Increase N_2O emission

216%

Nitrogen addition levels



The effect of nitrogen addition biogenic nitrous oxide emission

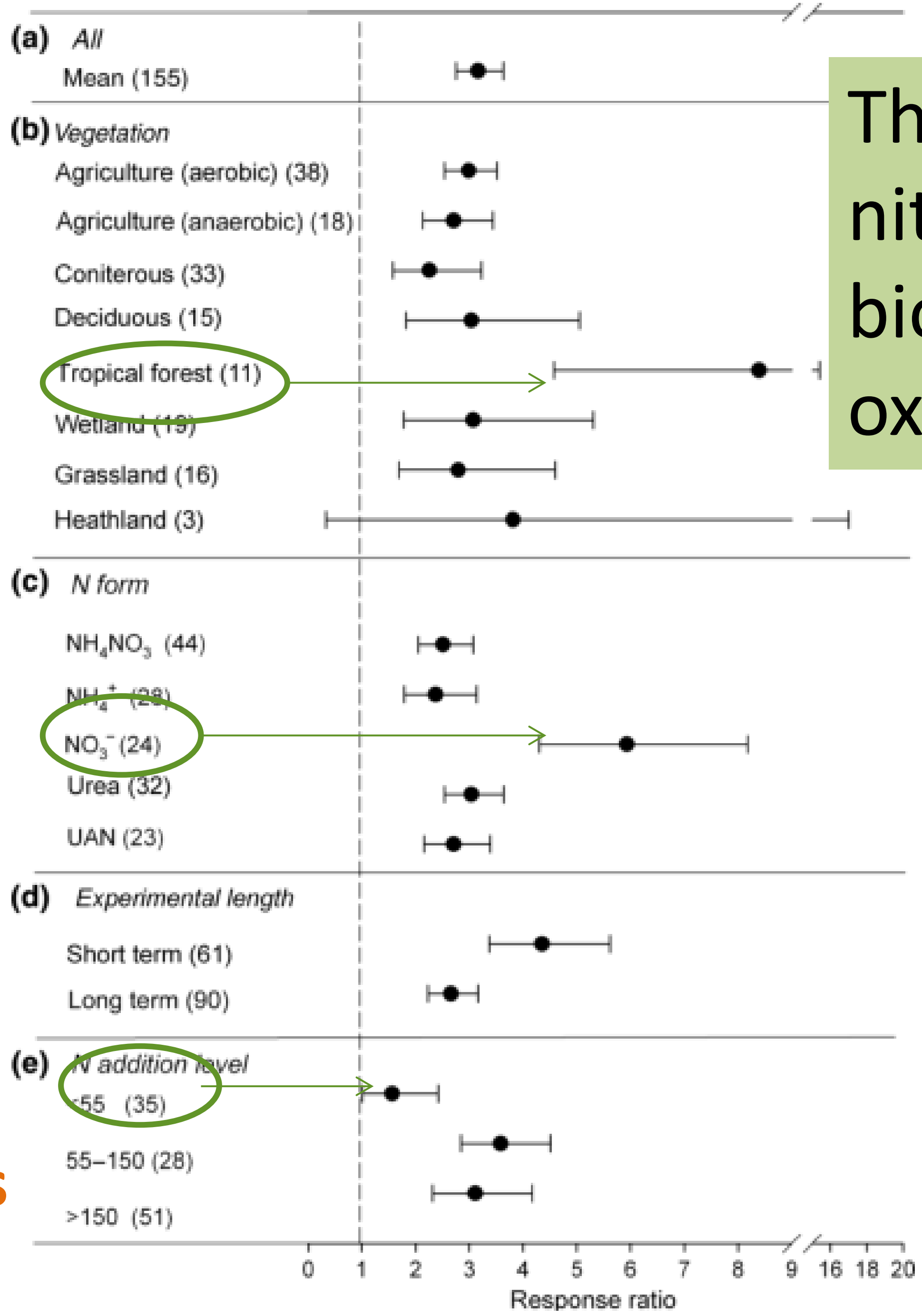
Figure 4

• 3. N_2O flux

Types of ecosystems

Forms of nitrogen

Nitrogen addition levels

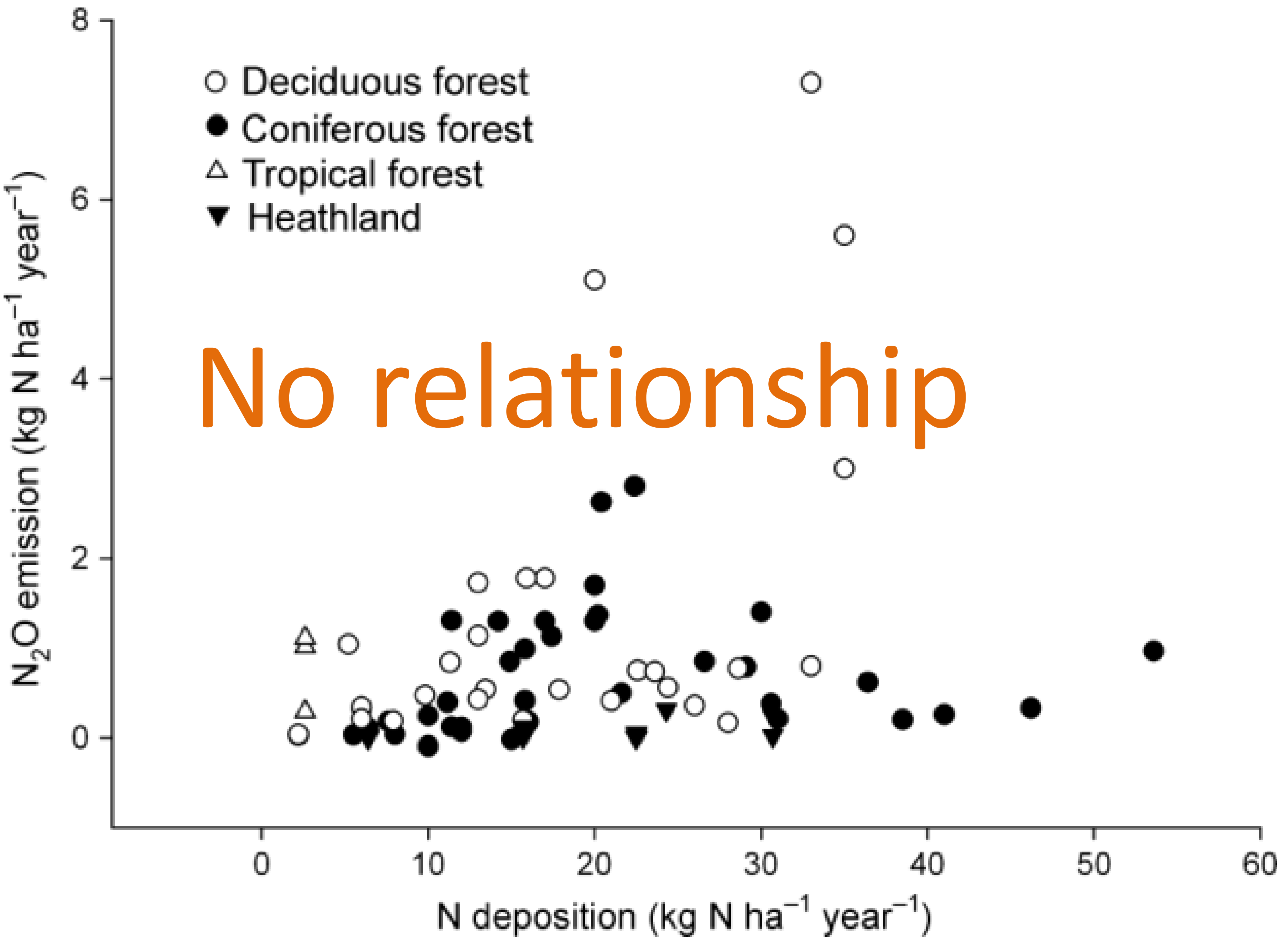


The effect of nitrogen addition biogenic nitrous oxide emission

Figure 4

Nitrogen deposition → ?

Relationship between nitrogen deposition and nitrous oxide emission



4. Global greenhouse gas budget

Table 4 Estimates of net changes in global biogenic greenhouse gases (GHG) flux caused by N enrichment

1.

		N-induced GHG emission/uptake factor (kg C or N ha^{-1} $year^{-1}$ per 1 kg N ha^{-1} $year^{-1}$)			
		CO_2-C	CH_4-C uptake	CH_4-C emission	N_2O-N
Forest		−24.5 ± 8.7	0.017 ± 0.005	0	0.006 ± 0.001
Grassland		0	0	0	0.006 ± 0.001
Wetland		0	0	0.008 ± 0.004‡	0.036 ± 0.013
Crop		−0.53 ± 0.1	0.012 ± 0.006¶	0.008 ± 0.004¶	0.009 ± 0.001
	Area (10^8 ha)§	The changes in CO_2 equivalents emission on global scale estimated by emission/uptake factor (Pg CO_2 per year)†			
Forest	41.6	−1.31 ± 0.46	0.098 ± 0.028	0	0.041 ± 0.007
Grassland	42.6	0	0	0	0.041 ± 0.007
Wetland	12.8	0	0	0.014 ± 0.007‡	0.075 ± 0.027
Crop	13.5	−0.31 ± 0.06	0.055 ± 0.027¶	0.004 ± 0.002¶	0.631 ± 0.070
Sum		−1.61 ± 0.35	0.153 ± 0.056	0.018 ± 0.009	0.788 ± 0.111
Global net change induced by N enrichment		0.655 ± 0.346 PgCO_2 per year (~0.179 ± 0.094 PgC per year)			
% CO_2 uptake offset by N_2O and GH_4 emission		53–76%			

2.

No sufficient data

Reference	Method	Ecosystem	N-induced sink
CO_2 uptake (Pg CO_2-C per year)			
Current study	Calculated from empirical data Data inputs: mean N addition rates; ecosystem specific C : N response ratio	Terrestrial ecosystem	↑ 0.35–0.58
Schindler & Bayley 1993	Calculated from empirical data Data inputs: Global anthropogenic sources and sinks of N; sinks of C based on various C : N ratios (50–150)	Terrestrial ecosystem	↑ 0.65–1.95
Townsend *et al.* 1996	Perturbation model (NDEP) Data inputs: global 1 × 1° resolution data for nitrogen deposition, climate, soil properties, vegetations	Terrestrial ecosystem	↑ 0.44–0.74
Holland *et al.* 1997	NDEP driven by five three-dimensional chemical models, GCTM, GRANTOUR, IMAGES, and MOGUNTIA Data inputs: NOx-N (or NHx-N) based on a latitude by longitude grid (2.4–10°) and meteorological data	Terrestrial ecosystem	↑ 1.42–1.97
CH_4 uptake (Tg CH_4-C per year)			
Current study	Calculated from empirical data Data inputs: mean N addition rates; ecosystem specific N-induced CH_4 emission factor	Terrestrial ecosystem	↓2.92–6.86
Reference	**Method**	**Ecosystem**	**N-induced emission**
N_2O emission (Tg N_2O-N per year)			
Current study	Calculated from empirical data Data inputs: mean N addition rates; ecosystem specific N-induced N_2O emission factor	Terrestrial ecosystem	↑ 1.43–1.90
Bouwman 1996	Calculated from empirical data Data inputs: global total N fertilizer use; global mean fertilizer-induced N_2O emission factor (1.25%)	Agriculture	↑ 1.0
Bouwman *et al.* 2002	Residual maximum likelihood-based model Data inputs: global 0.5 × 0.5° resolution data for soil properties, climate, land use, vegetation and fertilizer application	Agriculture	↑ 1.2*
Stehfest & Bouwman 2006	Same method as Bouwman *et al.* 2002;	Agriculture	↑ 1.1*
CH_4 emission (Tg CH_4-C per year)			
Current study	Calculated from empirical data Data inputs: mean N addition rates; ecosystem specific N-induced CH_4 emission factor	Terrestrial ecosystem	↑0.29–0.88

Summary of published estimations of nitrogen effects on the global biogenic GHG budget compared with the values from the current study

- N addition increased global terrestrial CO_2 sink. Carbon dioxide then decreased.
- N addition also increases global CH_4 emission, reduce CH_4 uptake and increase N_2O emission.
- CO_2 reduction could be largely offset by 53–76% from multiple ecosystems.

Nitrogen ⟶

CO_2 ↘

CH_4 ↗

N_2O ↗

Offset

53~76%

perspective:

1. only terrestrial ecosystem

2. not consider spatial complexity of N deposition & consequential heterogeneity of ecosystem response

3. limited empirical data for many regions and ecosystems

What I learned from this paper?

methodological→ **Meta-analysis**

The benefits:

large amount of observations contribute to more general and reliable results;
review the previous experiments and conclude their differences;

The limitations:

avoid artificial errors—careful selection