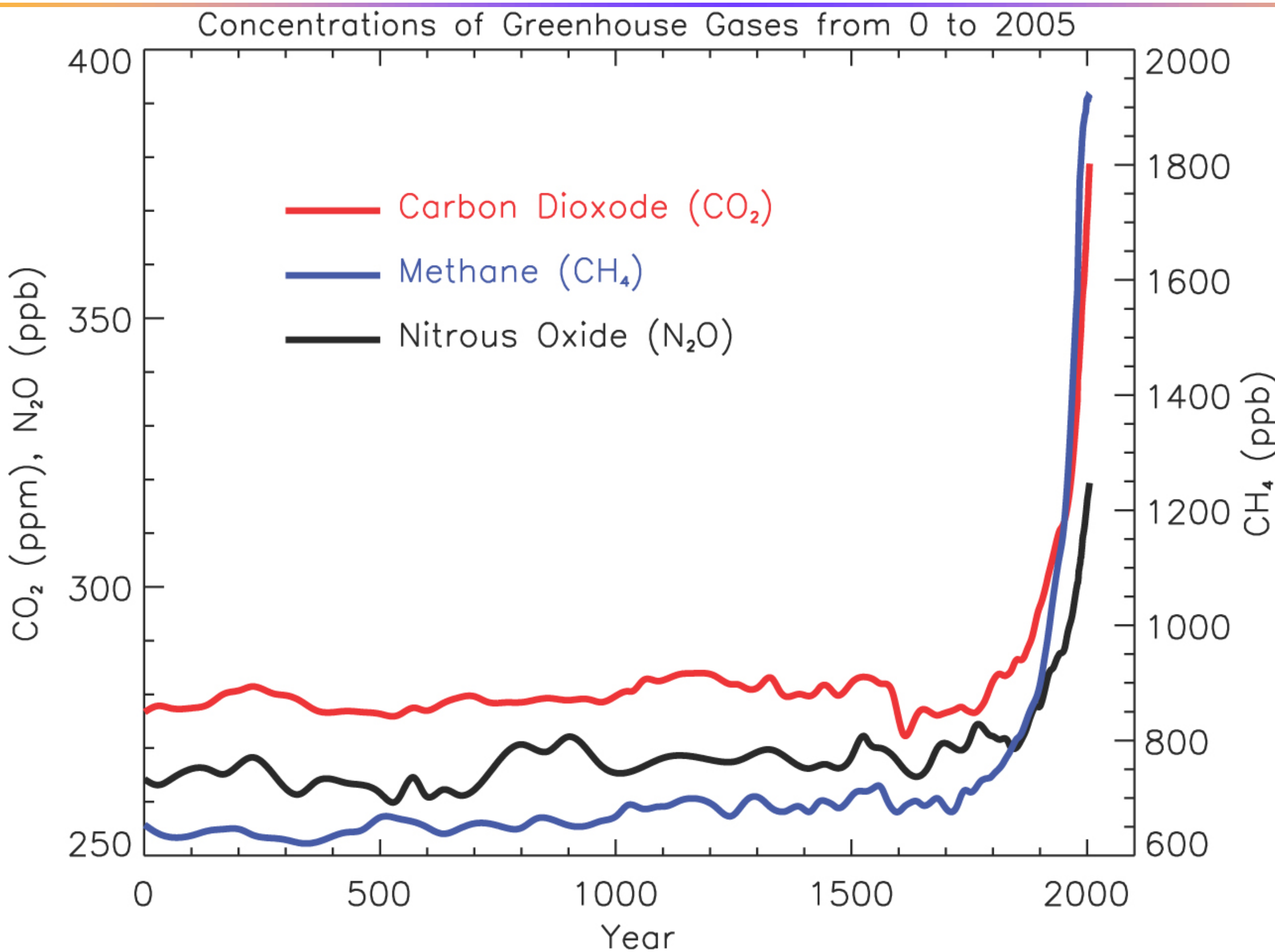
Indirect N_2O emission of a rice paddy-dominated watershed

XIA Yongqiu (夏永秋)
yqxia@issas.ac.cn

Increasing N_2O emission

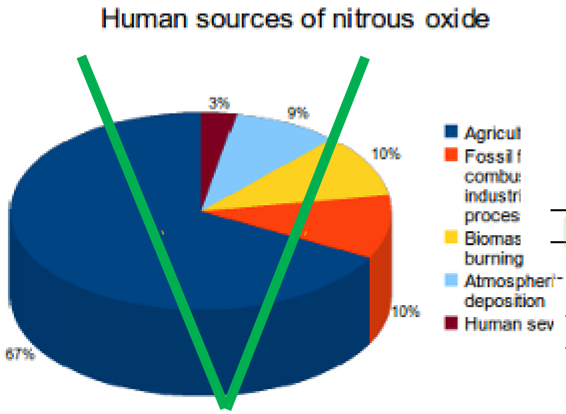


Direct V.S. Indirect N_2O emission

Direct emission

Table 6-17: Direct N_2O Emissions from Agricultural Soils by Land Use Type and N Input Type (Tg CO_2 Eq.)

Activity	1990	1995	2000	2005	2006	2007	2008
Cropland	**103.0**	**109.8**	**115.6**	**117.9**	**114.7**	**116.7**	**118.3**
Mineral Soils	**100.2**	**106.9**	**112.7**	**115.0**	**111.8**	**113.8**	**115.4**
Synthetic Fertilizer	35.1	39.8	39.0	41.4	39.4	40.3	40.8
Organic Amendments[a]	10.0	10.9	11.2	11.4	11.6	11.8	11.7
Residue N[b]	7.0	7.7	7.8	7.5	7.5	7.5	7.8
Mineralization and Asymbiotic Fixation	48.1	48.6	54.7	54.7	53.3	54.2	55.1
Organic Soils	**2.9**	**2.9**	**2.9**	**2.9**	**2.9**	**2.9**	**2.9**
Grassland	**53.7**	**51.9**	**50.2**	**52.6**	**51.3**	**50.5**	**52.1**
Synthetic Fertilizer	3.9	4.1	3.8	4.0	4.0	3.9	4.0
PRP Manure	10.3	10.8	10.3	10.5	10.4	10.3	10.4
Managed Manure[c]	0.7	0.7	0.7	0.8	0.8	0.8	0.8
Sewage Sludge	0.3	0.3	0.4	0.5	0.5	0.5	0.5
Residue N[d]	11.6	11.1	10.4	11.1	10.8	10.7	11.0
Mineralization and Asymbiotic Fixation	26.9	24.8	24.6	25.6	24.8	24.4	25.4
Total	156.7	161.8	165.8	170.5	166.0	167.2	170.4



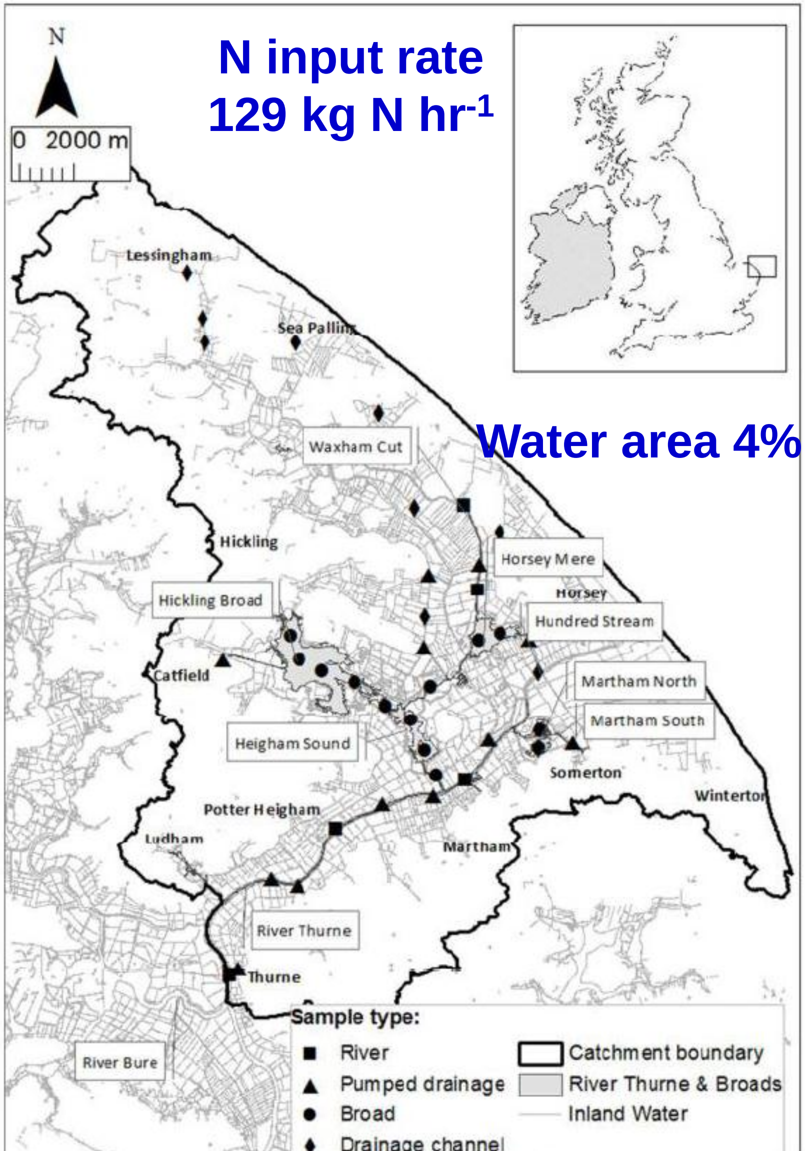
Indirect emission

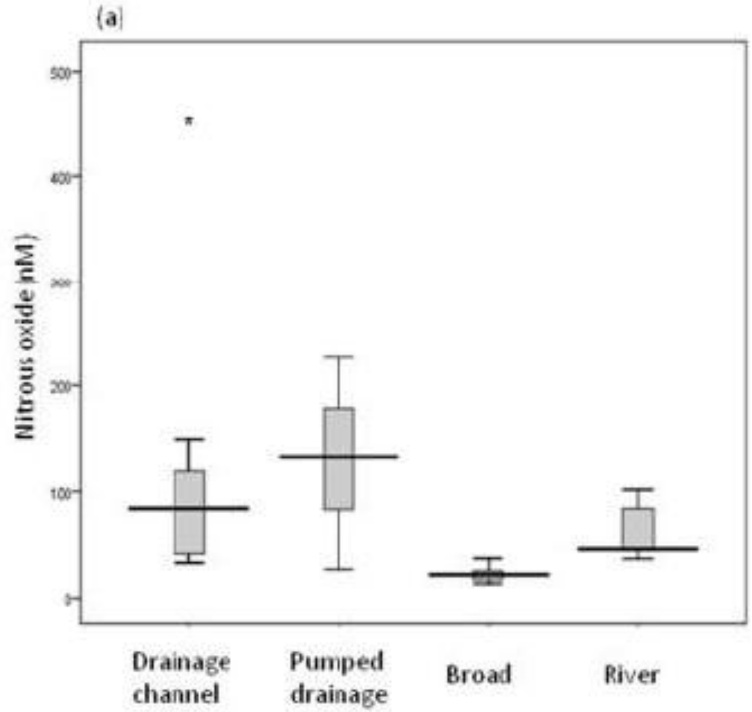
Table 6-18: Indirect N_2O Emissions from all Land-Use Types (Tg CO_2 Eq.)

Activity	1990	1995	2000	2005	2006	2007	2008
Cropland	**36.0**	**33.9**	**35.7**	**35.4**	**35.3**	**34.1**	**35.1**
Volatilization & Atm. Deposition	10.5	11.7	11.9	11.7	12.9	11.3	12.0
Surface Leaching & Run-Off	25.6	22.2	23.8	23.6	22.4	22.7	23.1
Grassland	**10.4**	**9.7**	**8.0**	**9.3**	**9.2**	**9.0**	**9.6**
Volatilization & Atm. Deposition	5.6	5.6	5.1	5.3	5.3	5.2	5.2
Surface Leaching & Run-Off	4.8	4.1	2.9	4.0	3.9	3.8	4.4
Forest Land	**+**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Volatilization & Atm. Deposition	+	+	+	+	+	+	+
Surface Leaching & Run-Off	+	+	0.1	0.1	0.1	0.1	0.1
Settlements	**0.3**	**0.5**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
Volatilization & Atm. Deposition	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Surface Leaching & Run-Off	0.2	0.3	0.3	0.4	0.4	0.4	0.4
Total	46.7	44.2	44.3	45.4	45.2	43.8	45.5

IPCC 2008 Methodology

Direct V.S. Indirect N_2O emission

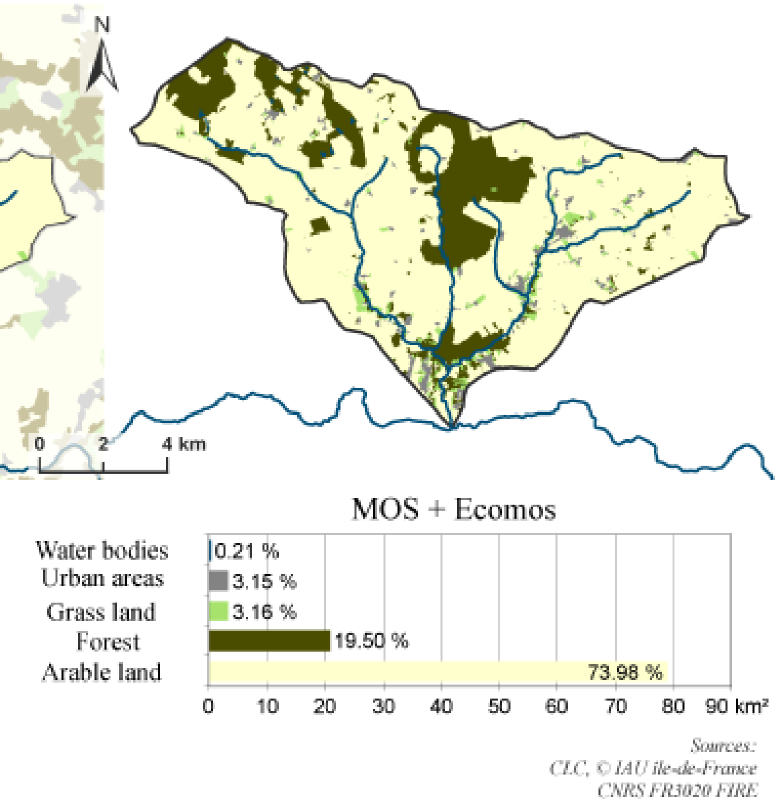




indirect N_2O emission account for 46% of the total N_2O emission

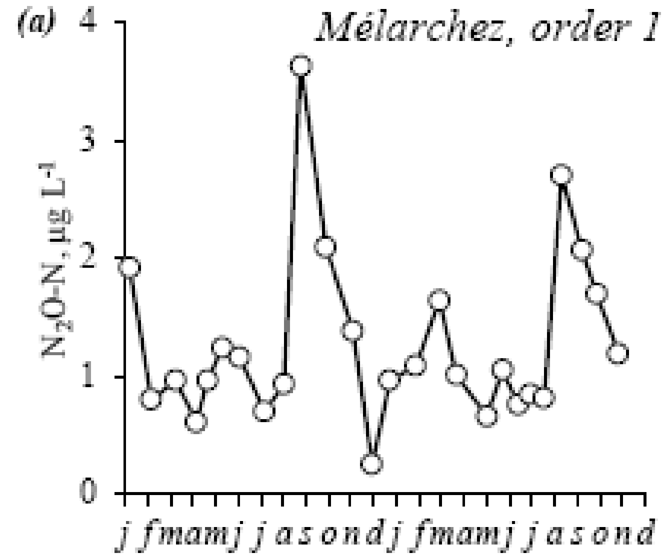
Outram, et al. 2012 EST

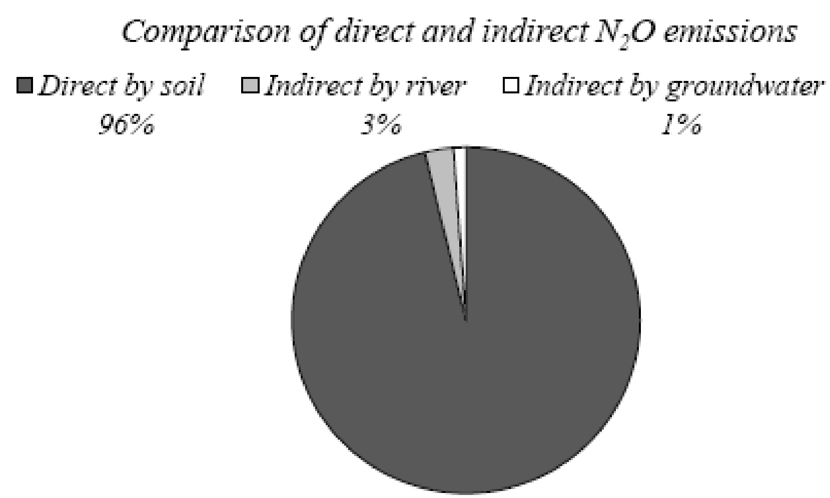
A significant indirect N_2O emission from agriculture



Water area 0.21%

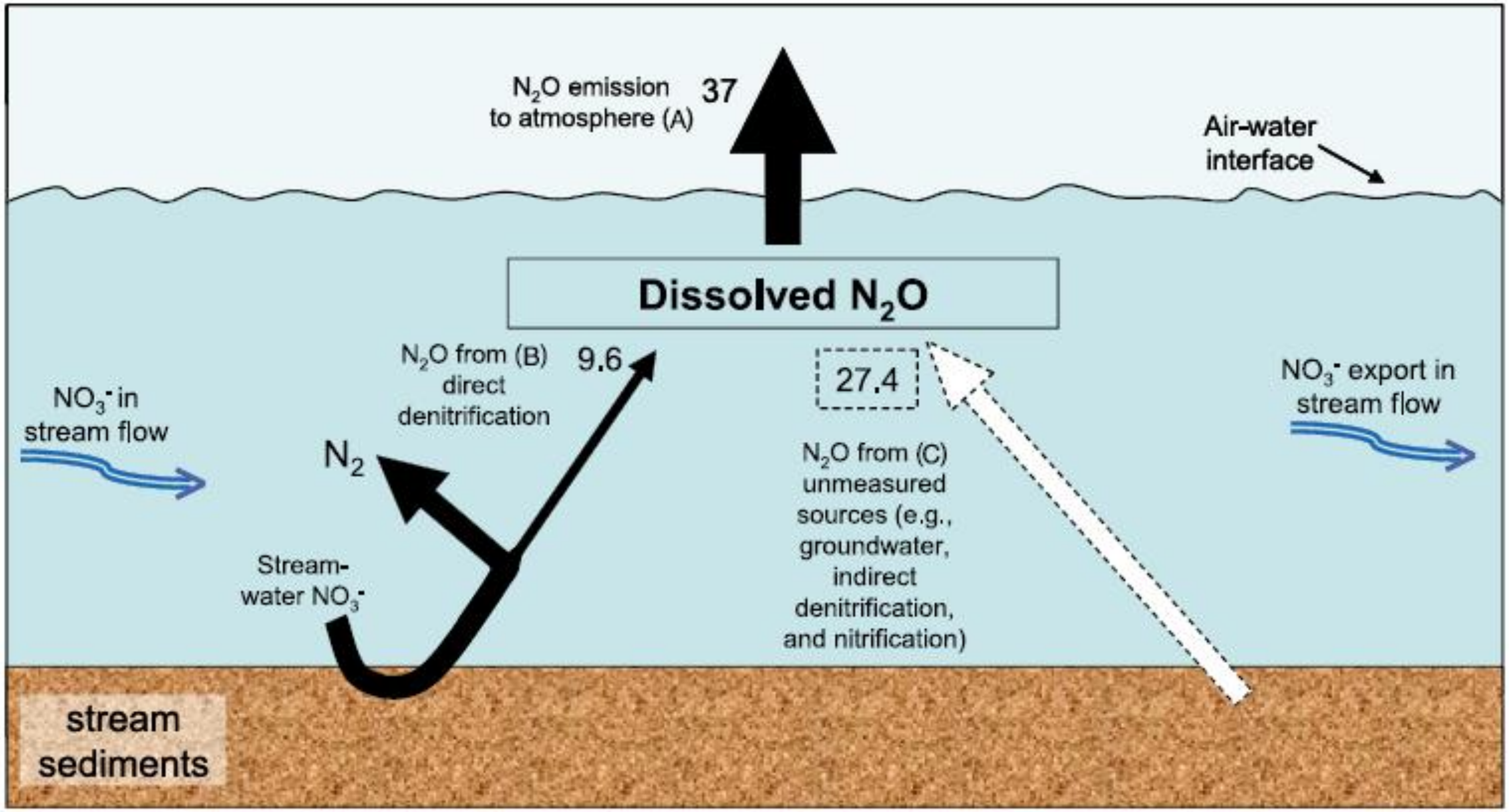
N input rate
185 +185 kg N hr^{-1}





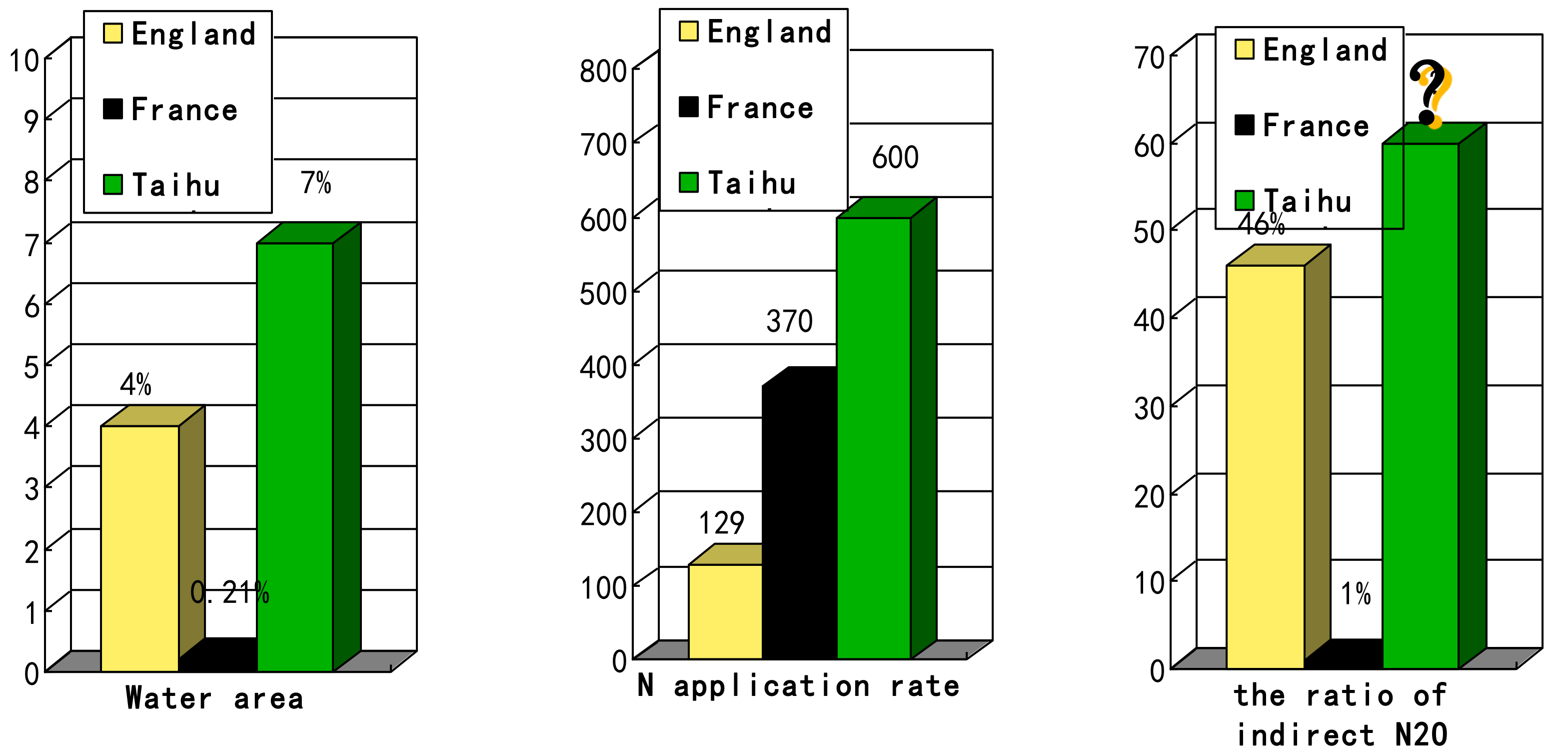
Vilain, et al. 2012 Biogeosciences

Production mechanism



Beaulieu et al. 2011 *PNAS*

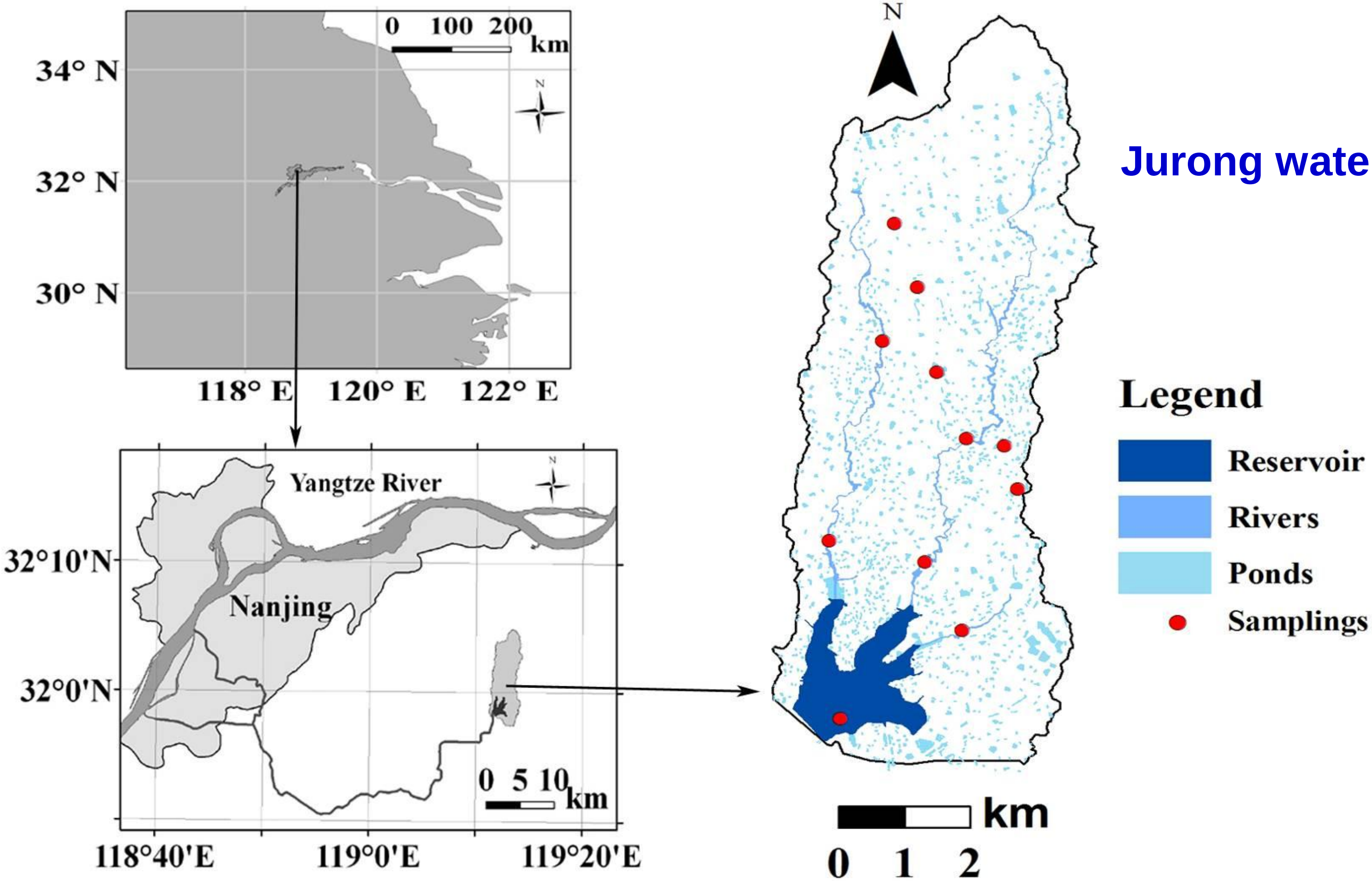
Question?



What is the ratio of indirect N_2O emission?

Is it a significant contributor to the agricultural greenhouse gas budget?

Study region



Jurong watershed

Water area 8.3%

N input rate （paddy rice +wheat）

300 +250 kg N hr^{-1}

Experiment design

- 5 ponds sites, 3 river sites, and 1 reservoir site
- dissolved N_2O were collected in 29-mL serum vials previously evacuated according the method of Terry et al. (1981)
- two years' continues sampling every 15-20 days
- DO、inorganic N、temperature、pH, and Eh of surface water were also measured

N_2O emission rate calculation

- Gas exchange across the water–air interface is calculated by the 'stagnant – two - film' （Liss and Slater, 1974, *Nature*）

$$F_{N2O}=V_{tot}（C_w-C_a/K_H）$$

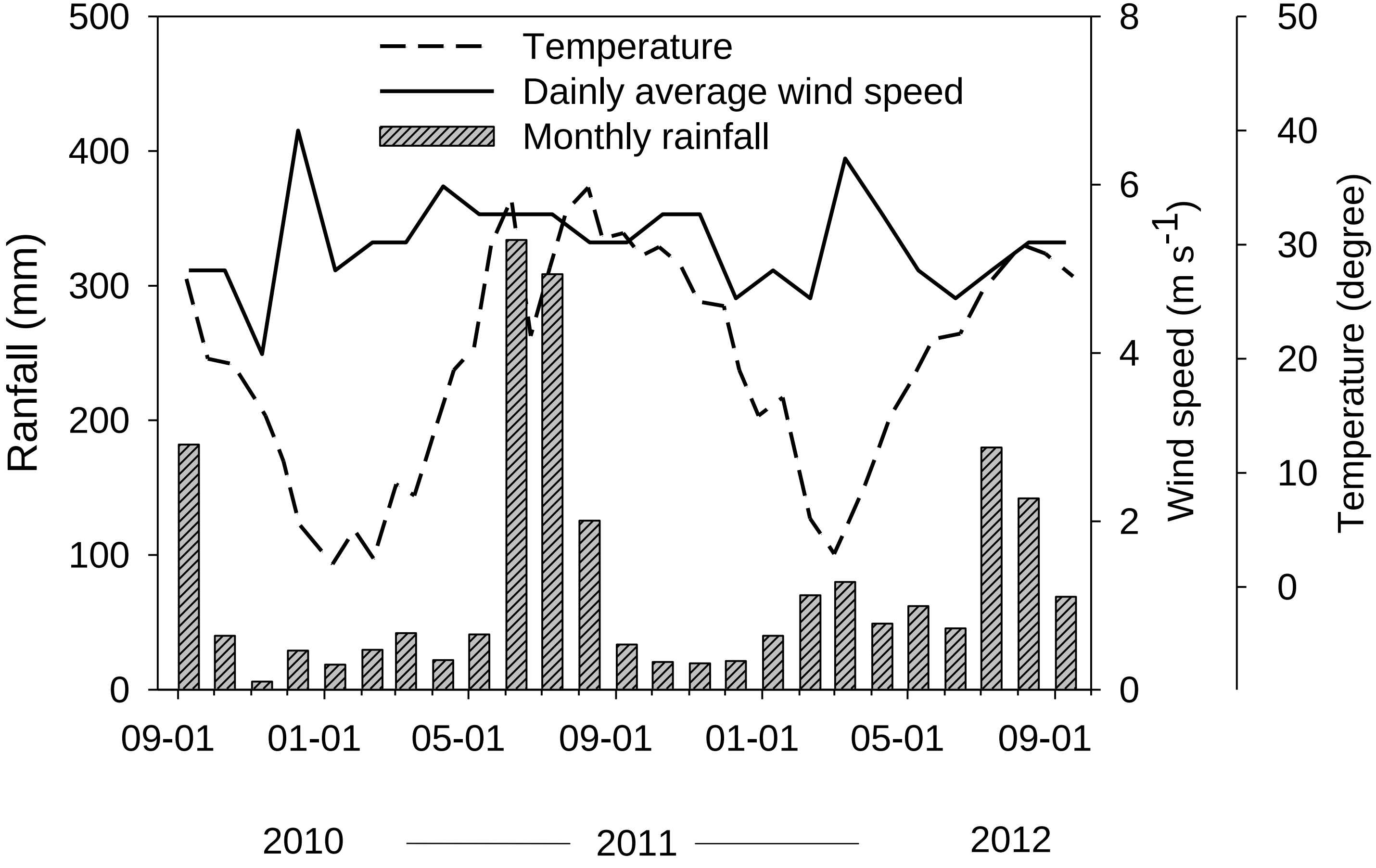
V_{tot} : the transfer velocity (m s^{-1}) for N_2O across the water-air interface

C_w: the N_2O concentration in the surface water of rivers, ponds, and reservoir (mol m^{-3})

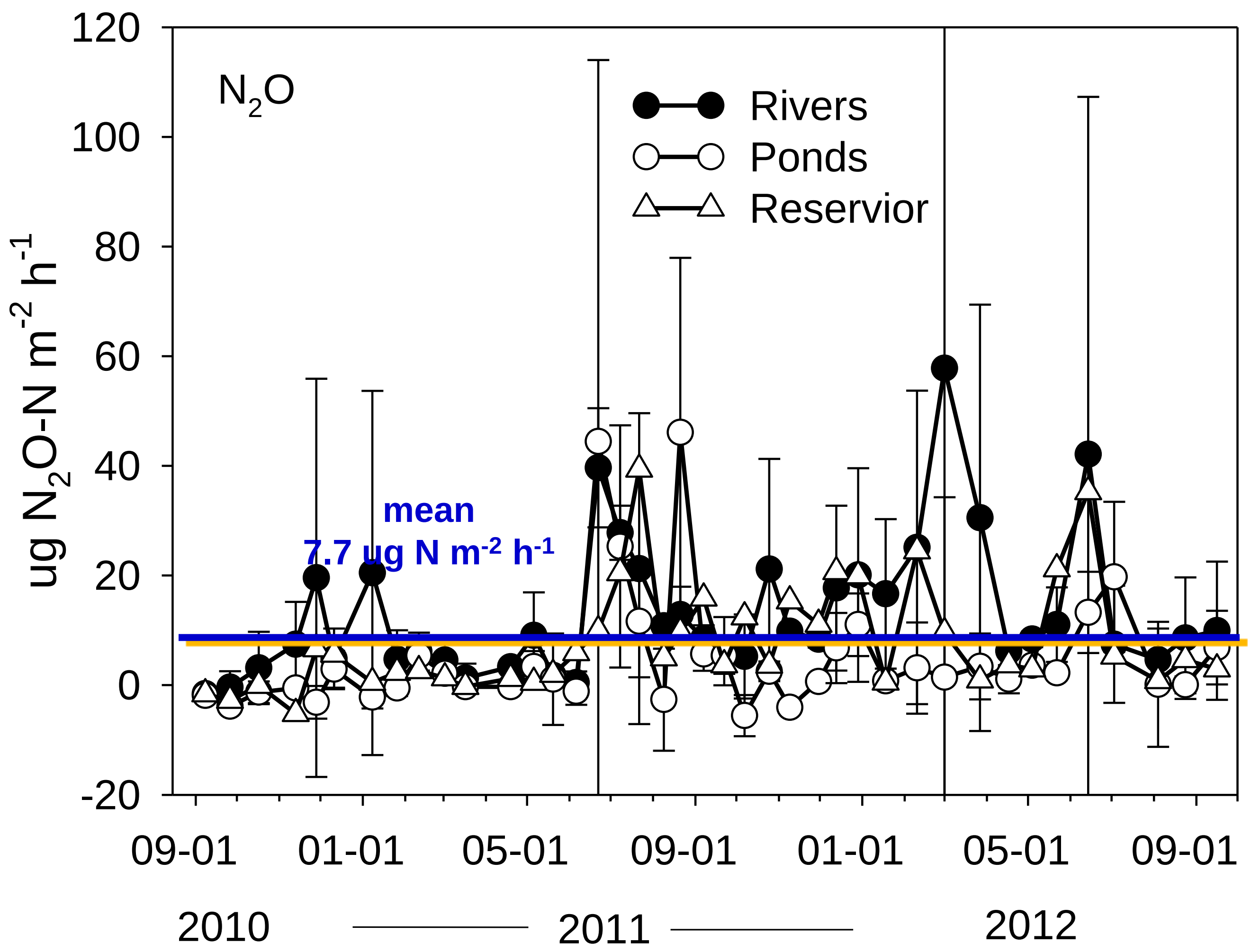
C_a: the N_2O concentration in ambient air (mol m^{-3}),

K_H: the dimensionless Henry's Law constant (mol m_a^{-3} mol m_w^{-3})

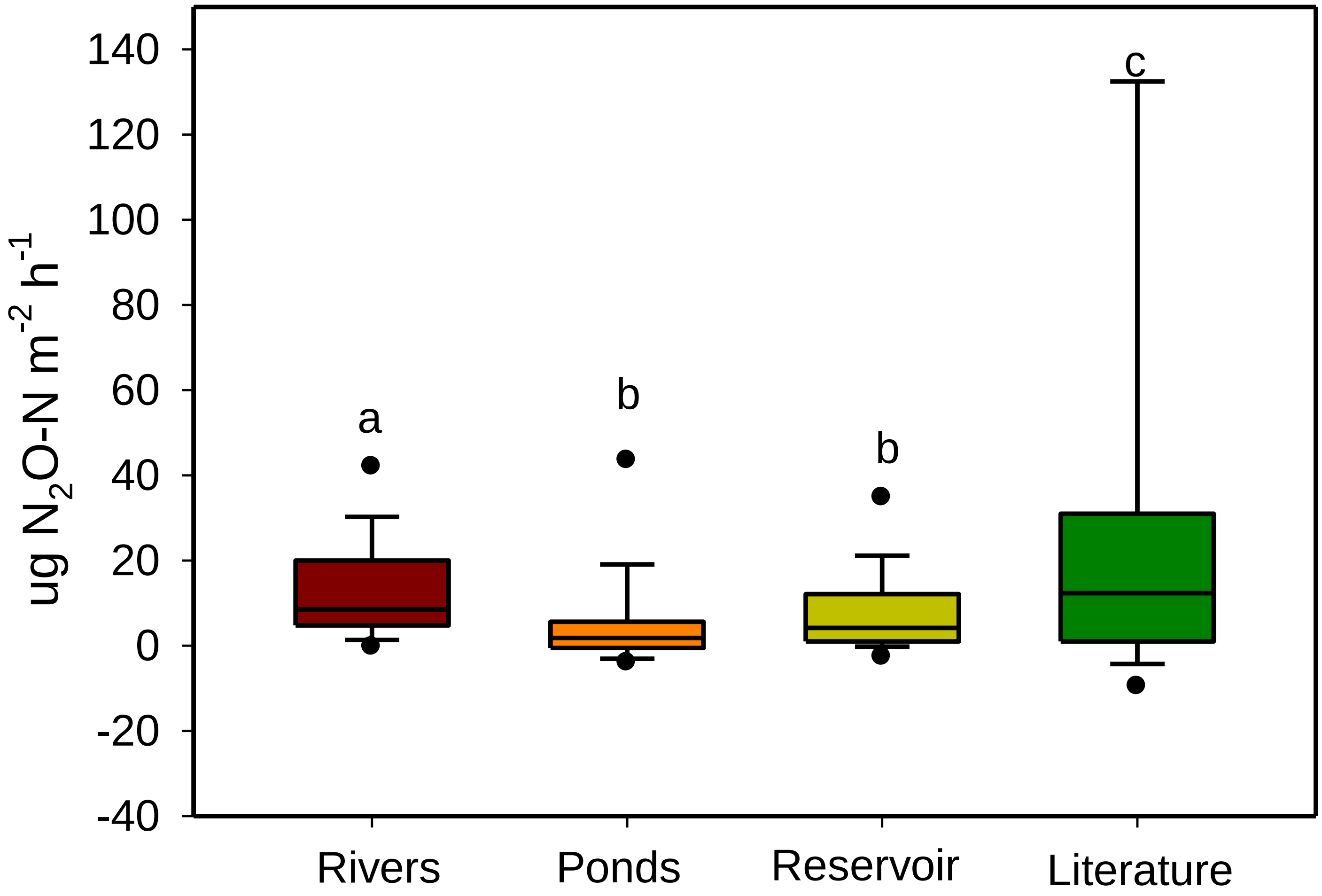
Climate parameters



Indirect N_2O emission rate



Compared to the references



Total indirect N_2O emission

Water body	Mean N_2O emission rates μg N m^{-2} h^{-1}	Water area ha	Indirect N_2O flux ton N $year^{-1}$
River	12.9(± 21.8)	32	0.036
Pond	4.5(± 16.3)	110	0.043
Reservoir	7.9(± 10.0)	230	0.16
In Total		373	0.24

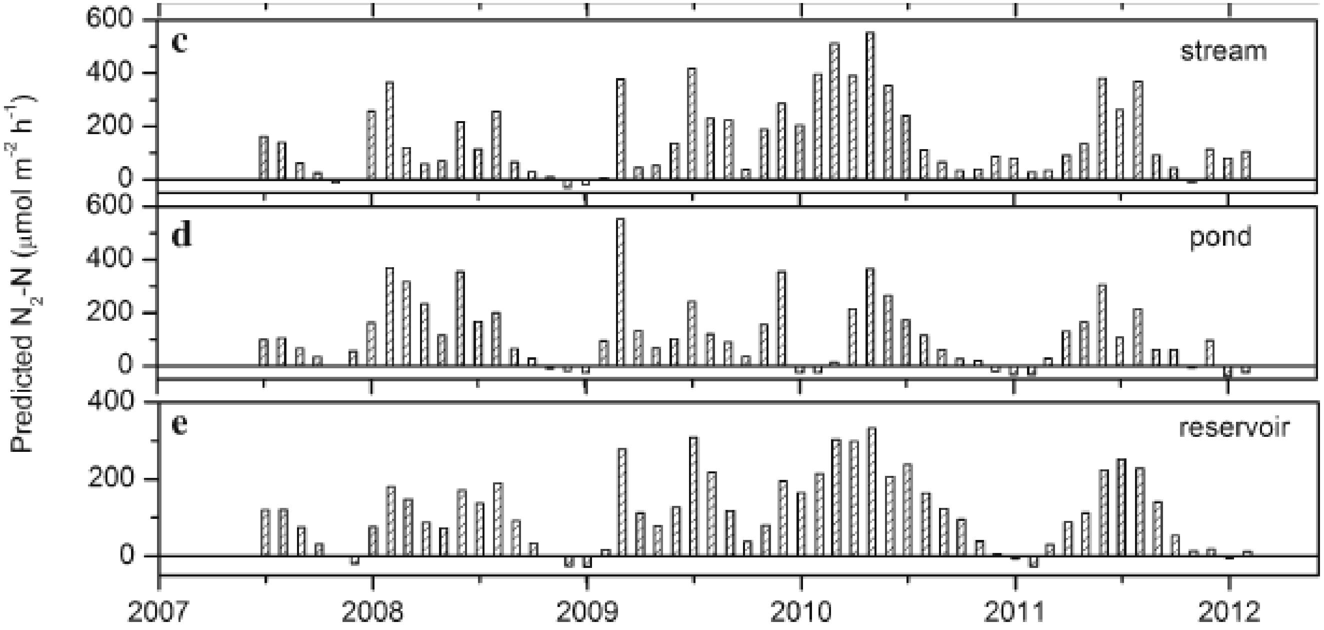
Compared to direct N_2O emission

crop	Total area (ha)	N applications rate (kg N ha^{-1})	Emission factor	**Direct N_2O emission (ton N $year^{-1}$)**
Rice	1422	329	0.0042	**1.96**
Cotton	516	228	0.02	**2.35**
Maize	229	167	0.02	**0.76**
Soybean	200	18	0.02	**0.07**
Oil rape	973	227	0.02	**4.42**
Wheat	712	212	0.02	**3.02**
Tea	50	41.7	0.02	**0.04**
Total				**12.63**

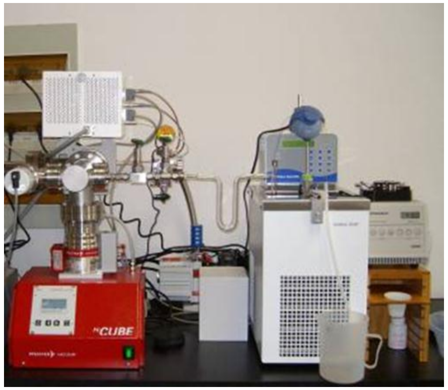
Yang, et al. 2010 SSPN

$$\frac{\text{Indirect } N_2O}{\text{total } N_2O} = \frac{0.24}{0.24+12.63} \times 100\% = 1.8\%$$

Compared to N removed by denitrifiation



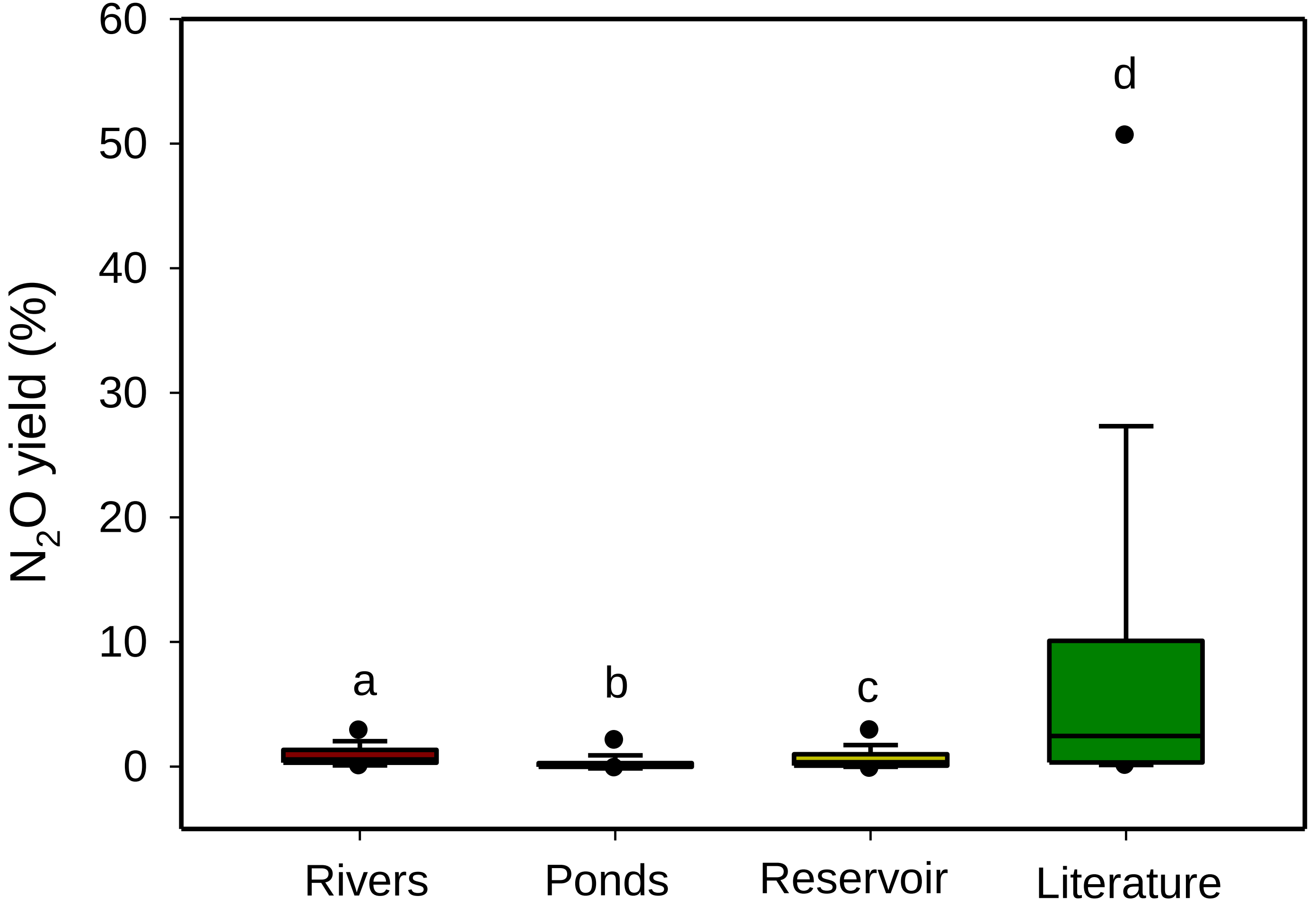
membrane inlet mass spectrometry method



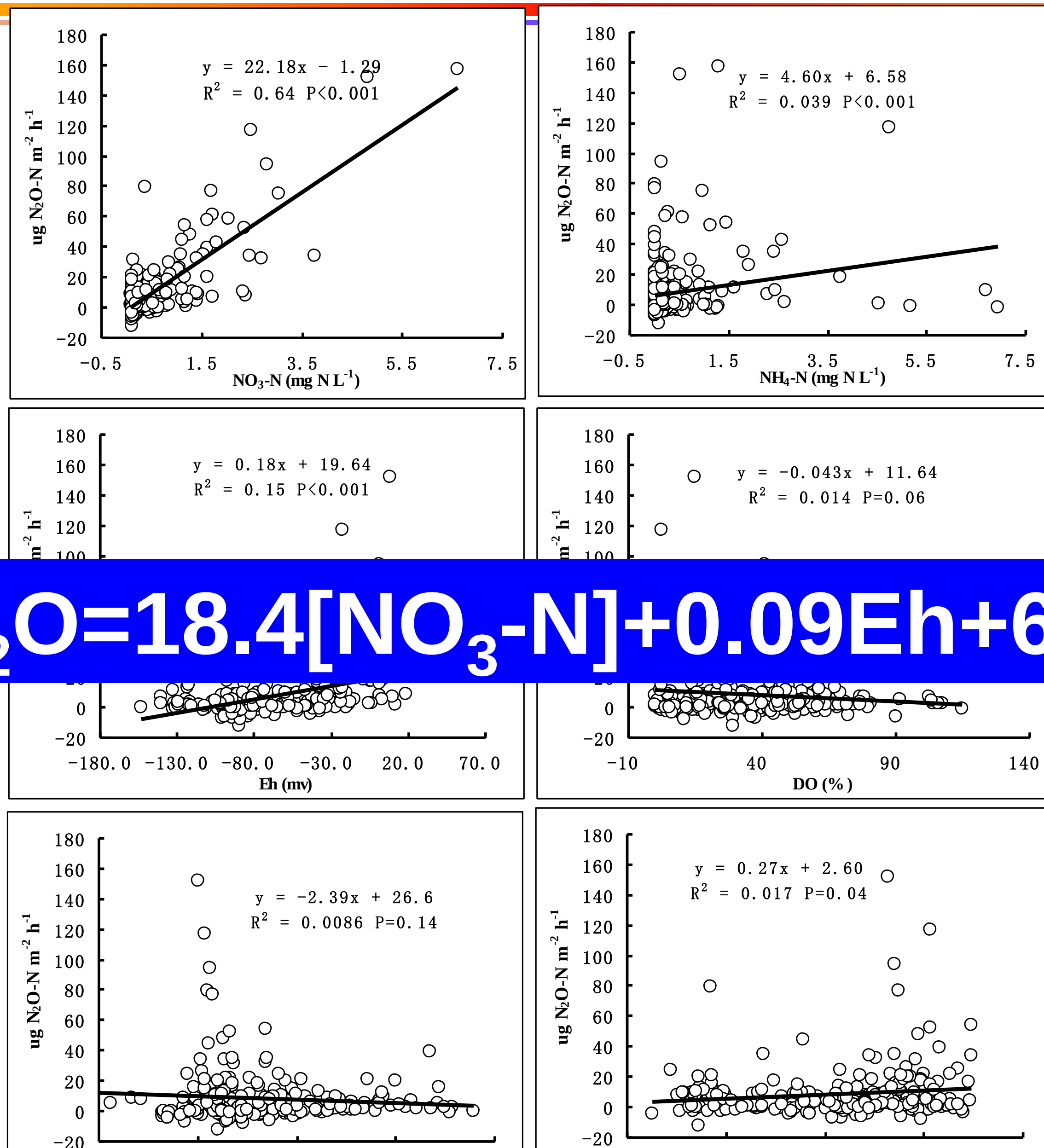
Li, et al. 2013 JSS

Water body	Indirect N_2O ton N year^{-1}	N removal (ton N year^{-1})	N_2O:N_2 %
River	0.036	4.1	0.88
Pond	0.043	18.4	0.24
Reservoir	0.16	24.4	0.65
In Total	0.24	46.8	0.51

Compared to the references



What are reasons resulting in low N_2O emission？

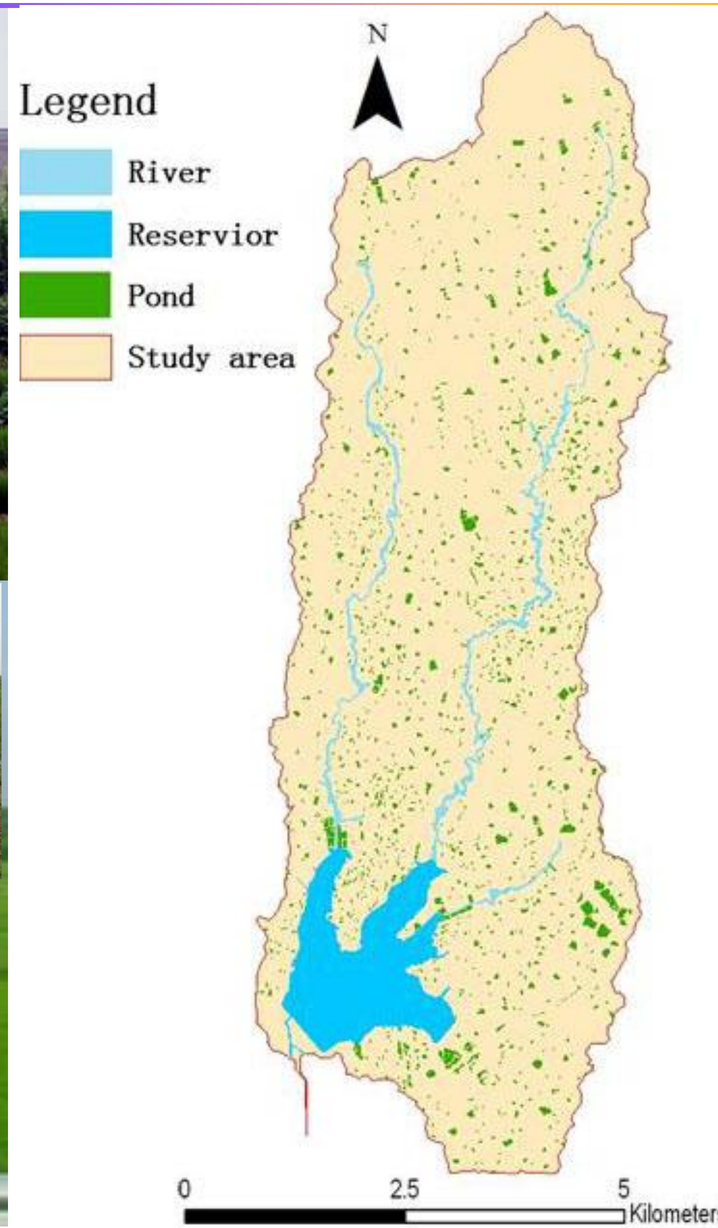


$$N_2O=18.4[NO_3\text{-}N]+0.09Eh+6.1$$

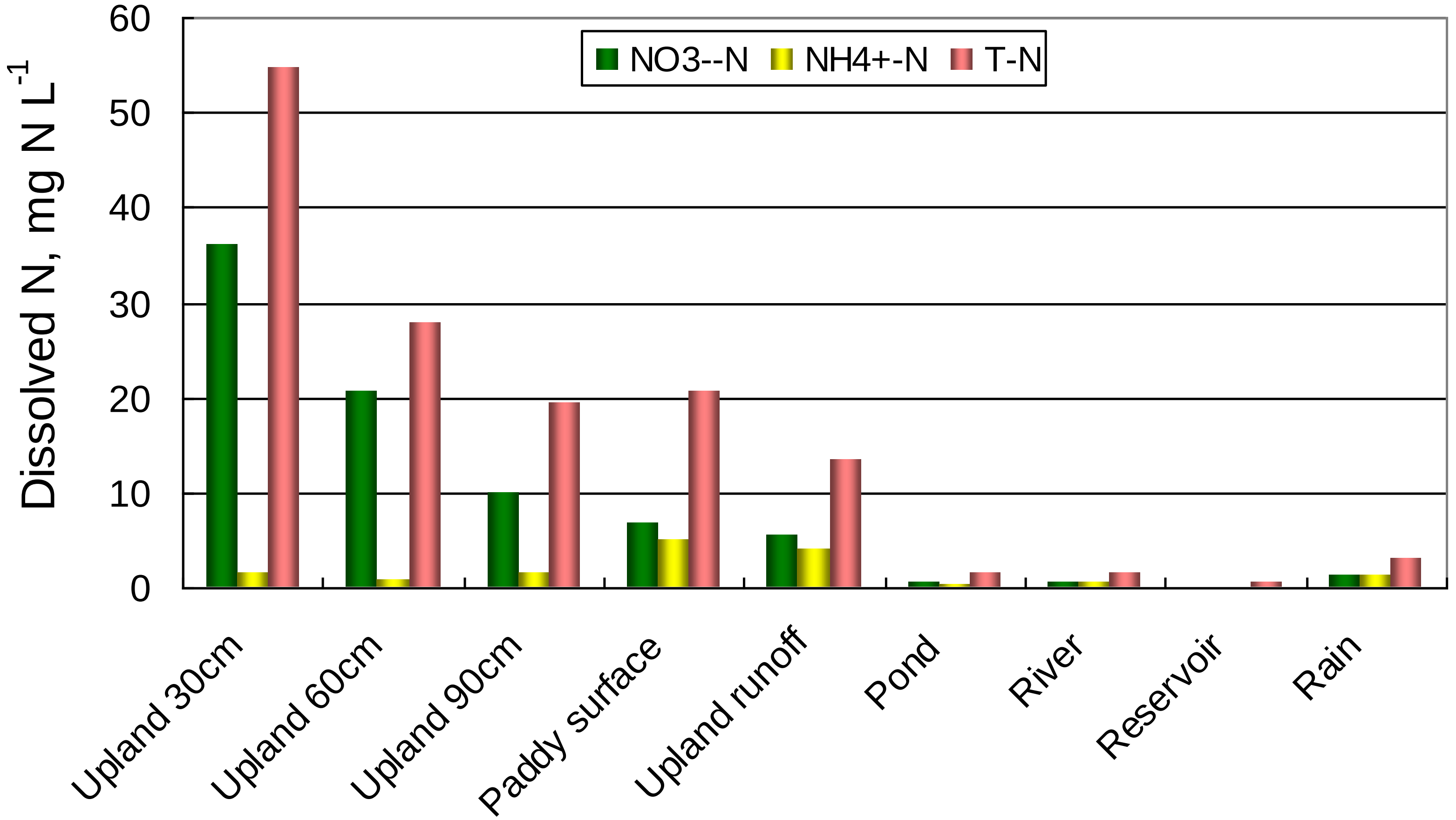
Great runoff is intercepted

Run-off in million m^3

Great runoff is intercepted

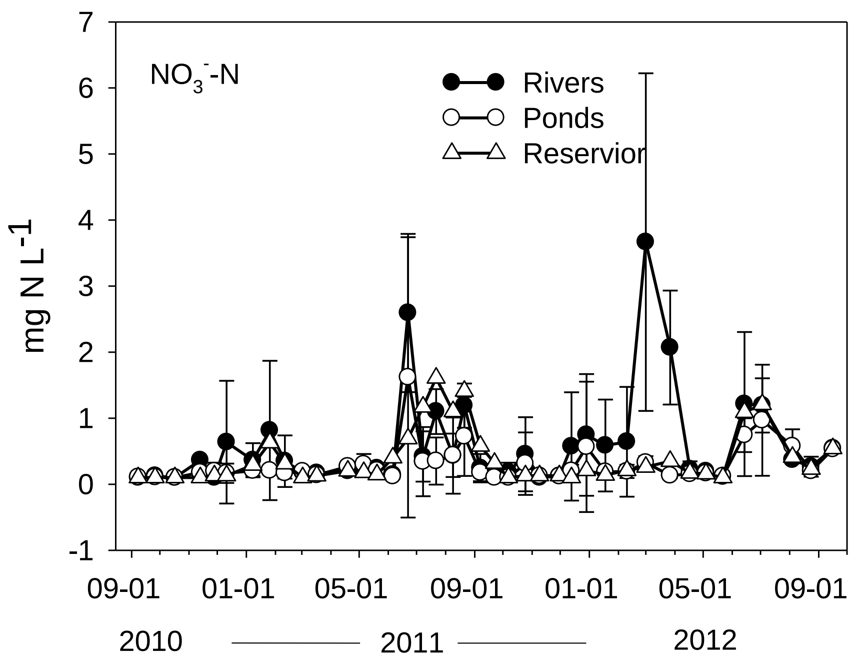


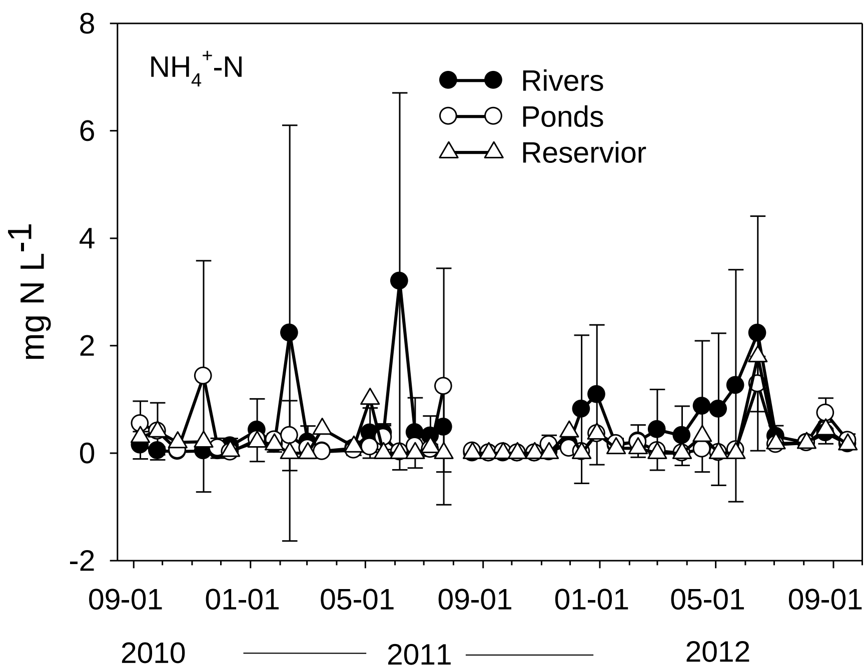
Great runoff is intercepted



N concentrations through transport

Great runoff is intercepted



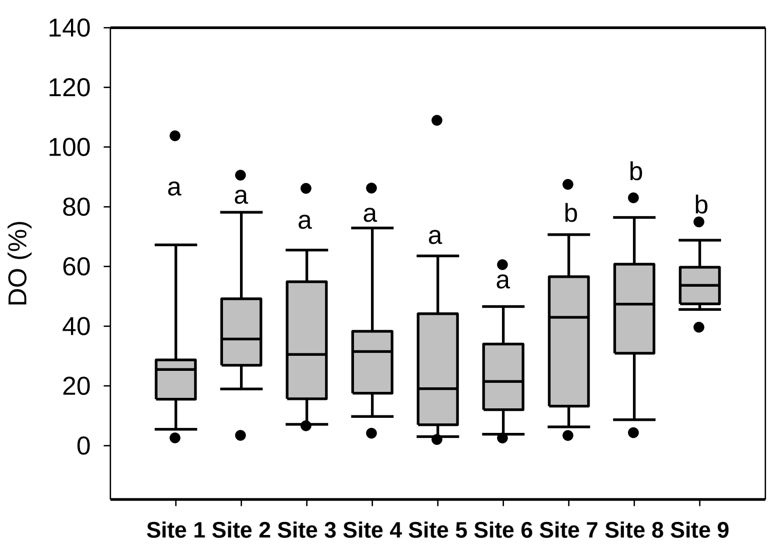


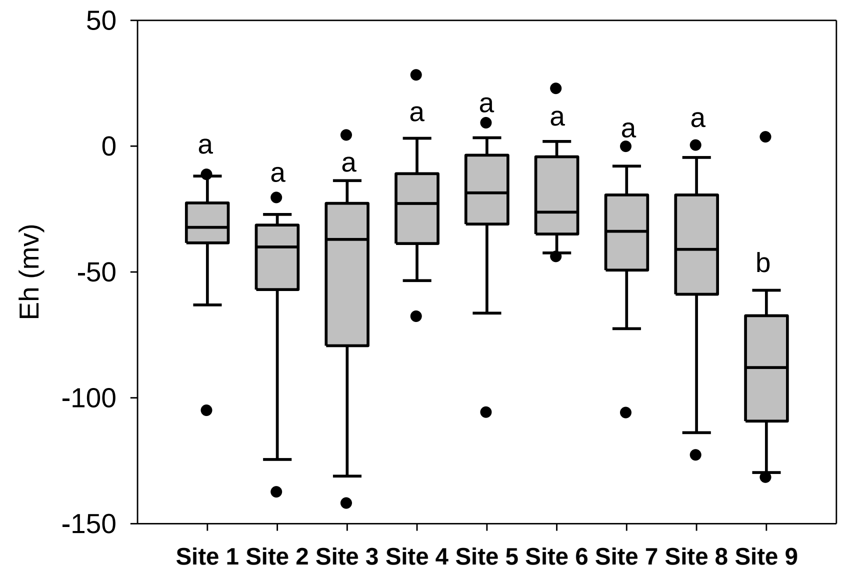
As a result, N concentration of outflow is very low

High reducing condition

Low water velocity

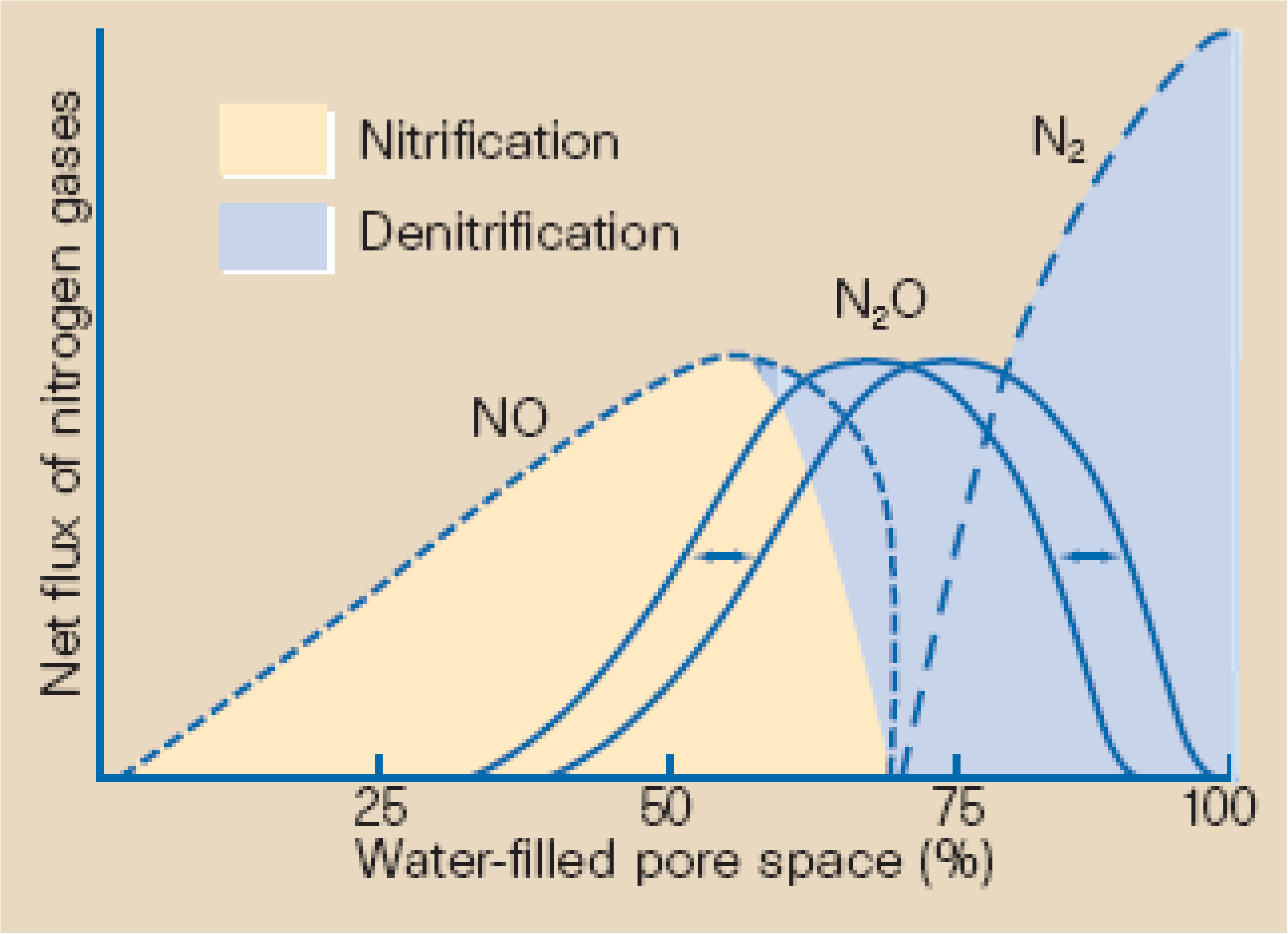
High reducing condition





Ponds site:Site1-site 5； river sites: site 6-site 8；reservoir site: site 9

High reducing condition

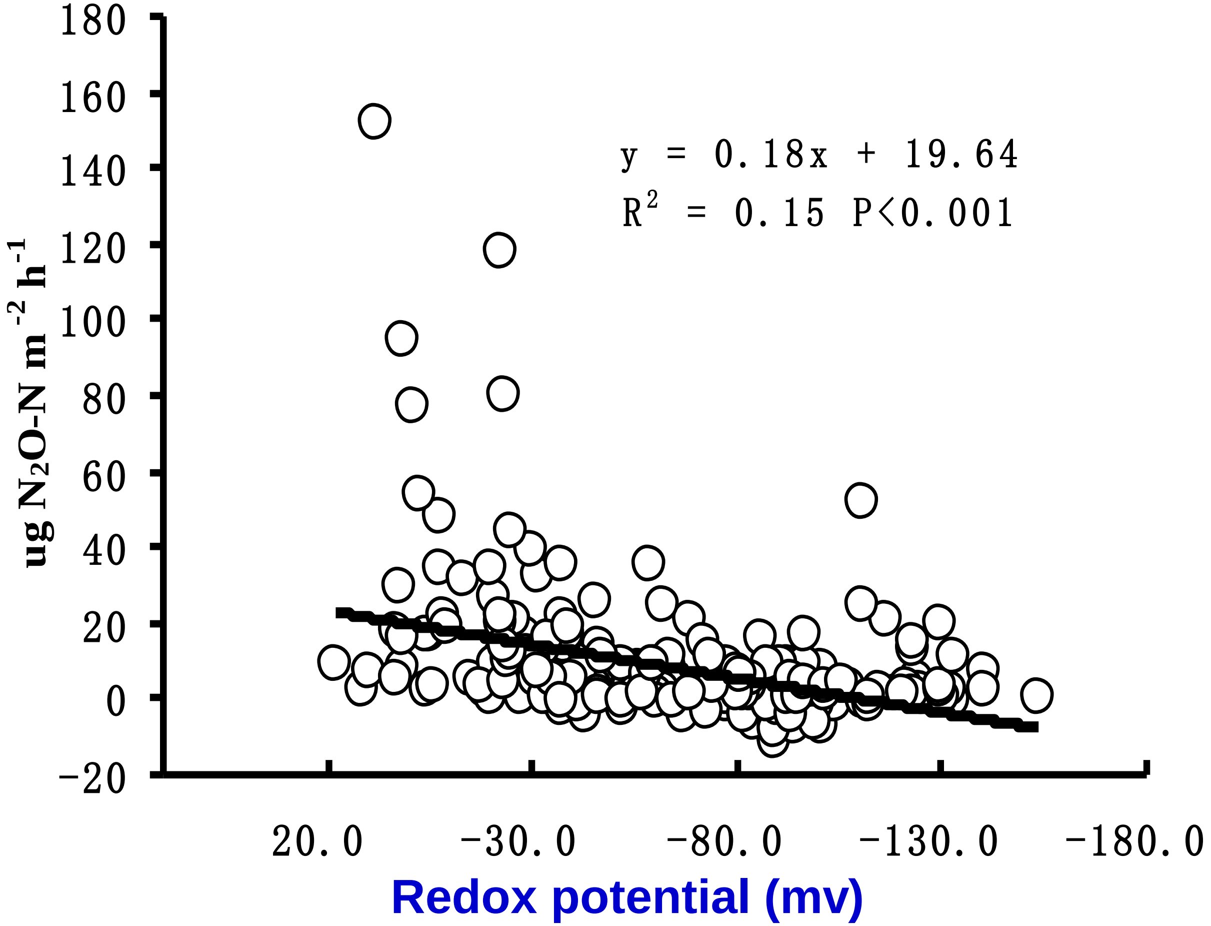


Bouman, 1998 *Nature*

Decreasing N_2O/N_2 ratio

High reducing condition

$NO_3^- \rightarrow NO_2^- \rightarrow \mathbf{N_2O} \rightarrow N_2\uparrow$

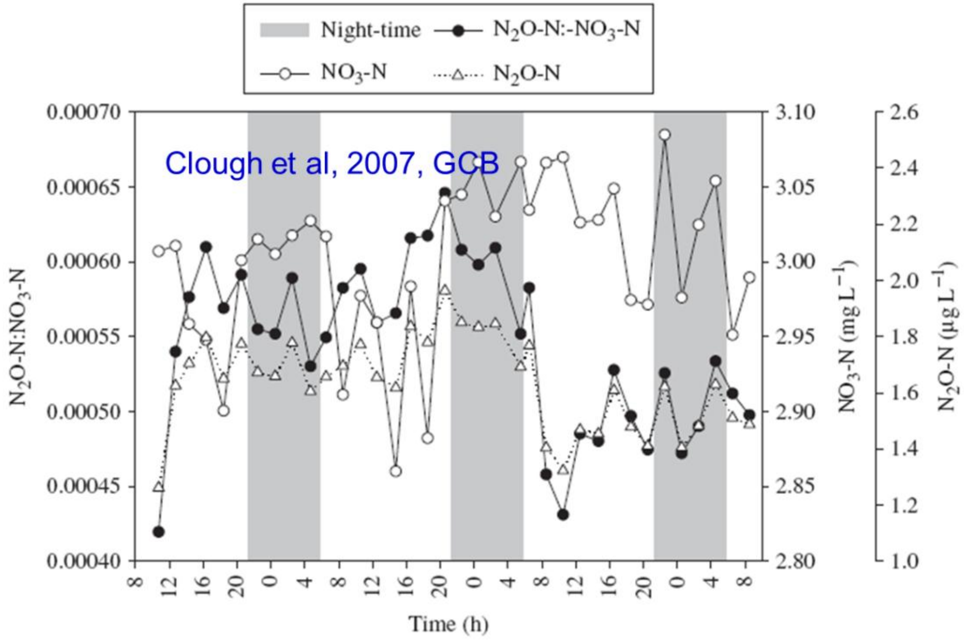


Conclusions

- 1 Though water area is high and N input rate is as high as 600 kg N ha^{-1} per year in our paddy rice dominated watershed, indirect N_2O emission is disproportionately low.
- 2 This could have resulted from the limited inputs of N into waterways
- 3 Strong reductive conditions as a result of low water velocity might also play a great role.

Question?

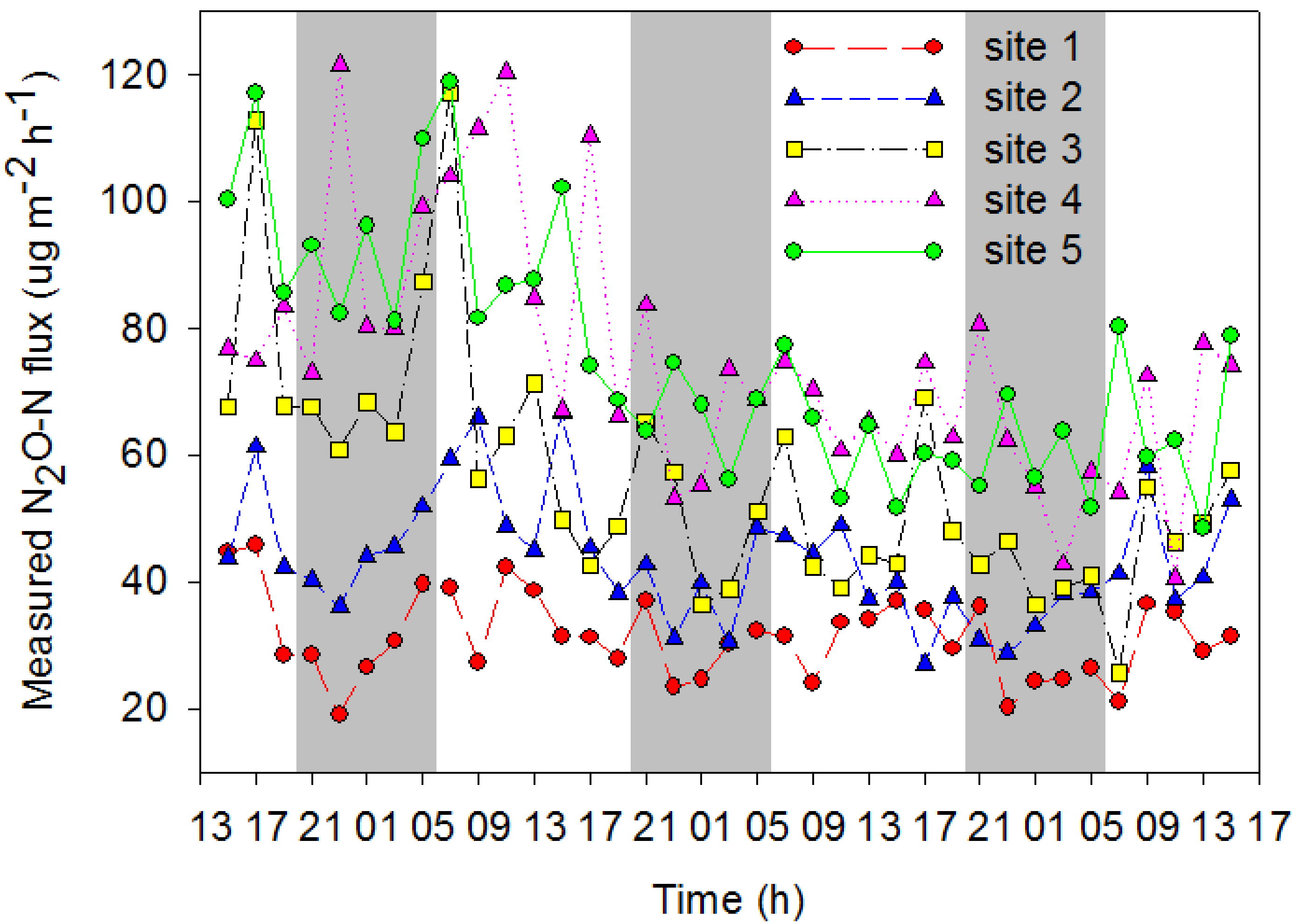
- Sampling method?
- Sampling time?
- Sampling site?



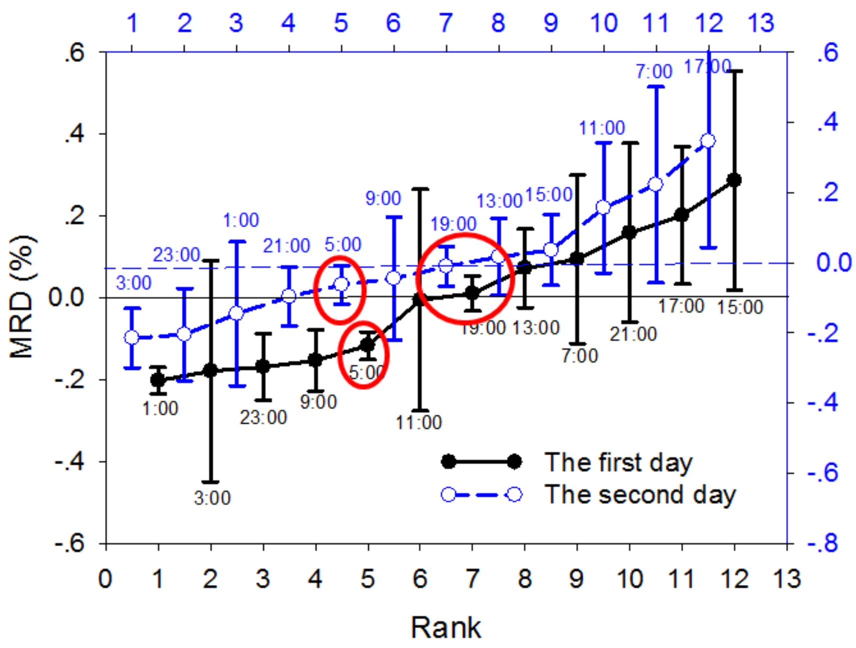
Floating chamber method

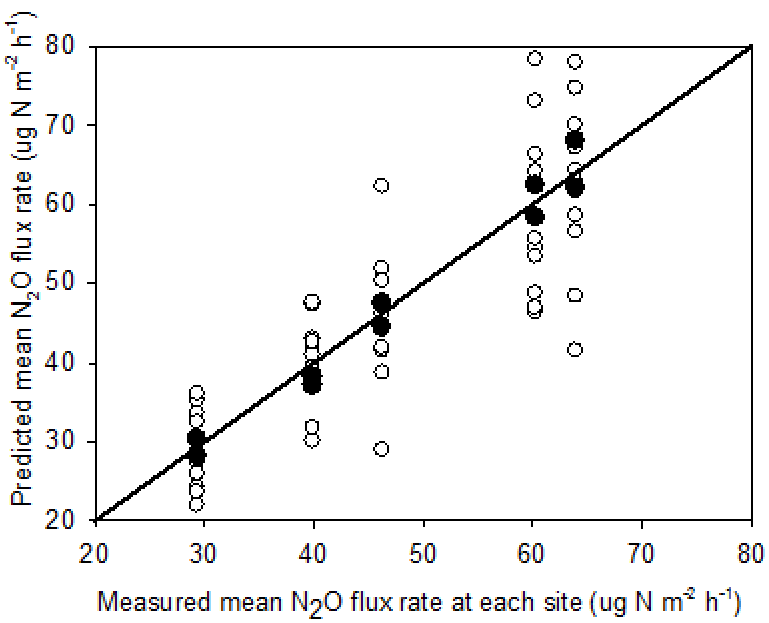
国家专利号：**201120210689.2**

Hourly variated emission rate

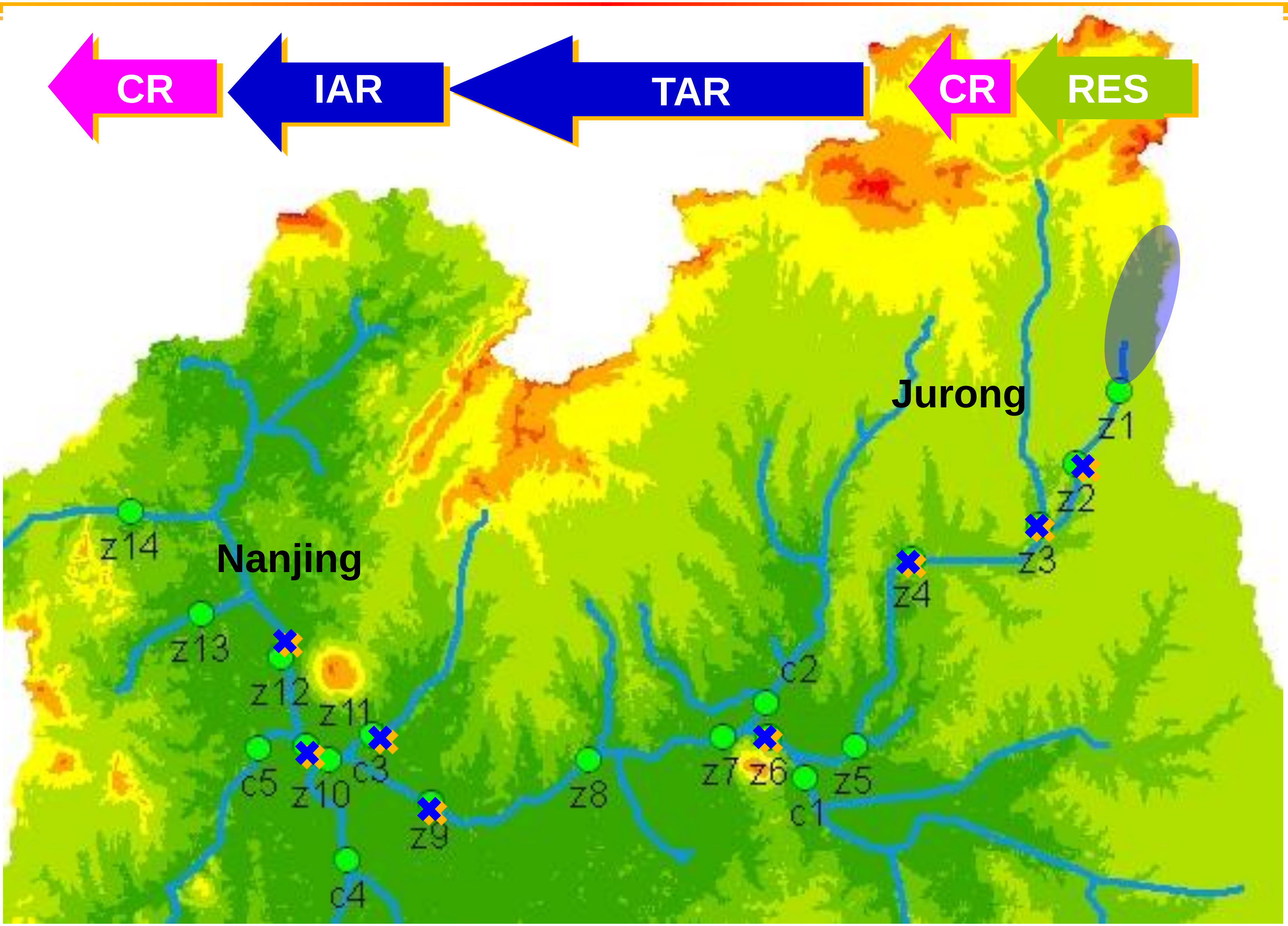


The best sampling time

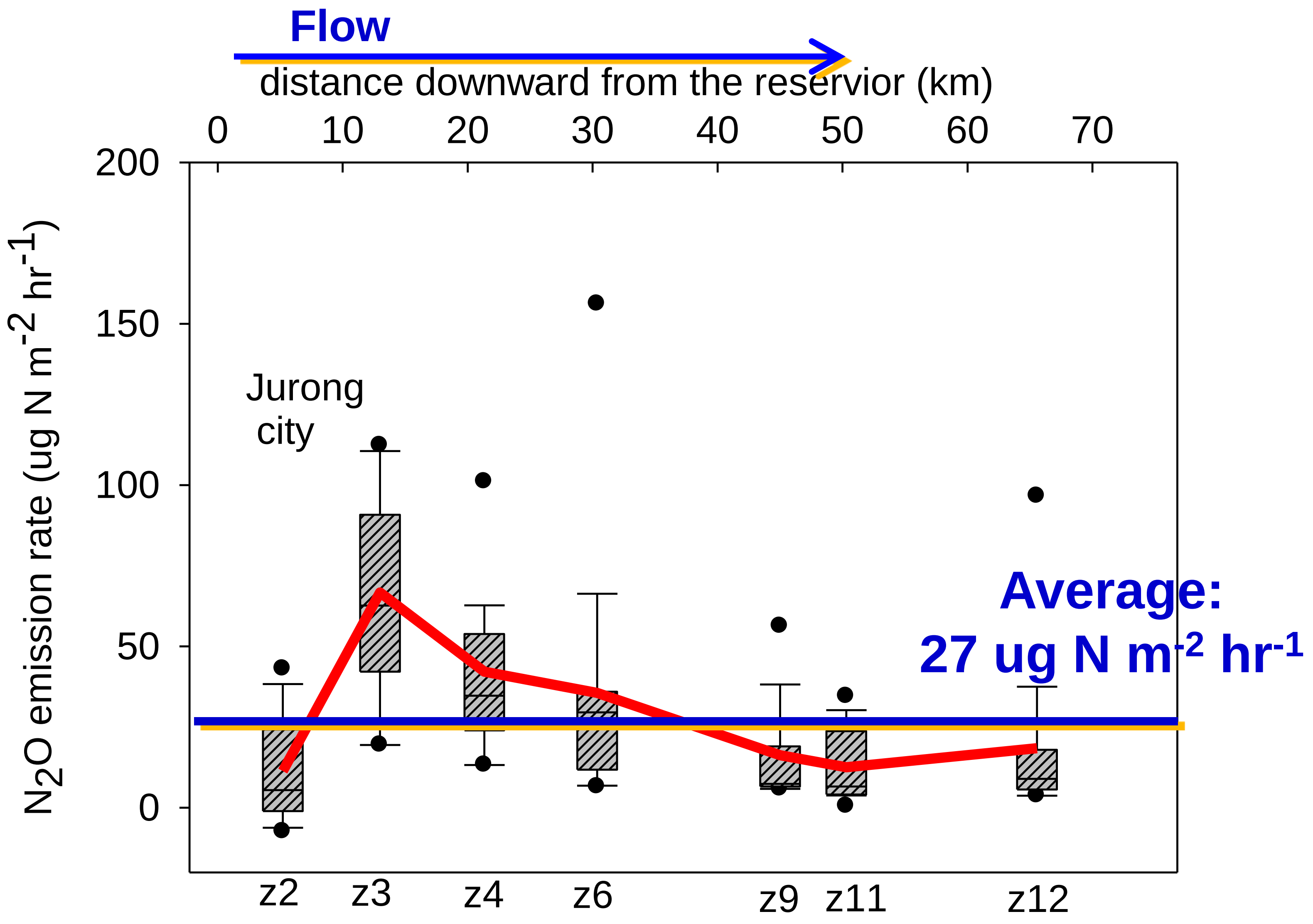




Study region and sample sites



Spatial variation of riverine N_2O emission



Still continuing……

References

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Thanks a lot!