Large Scale Experiments on Methane and Nitrous Oxide Emissions From Rice Fields

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Outline

1) Do we have reliable country-wide (or global) estimates of CH_4 emissions from rice fields?
No.

2) Why?

1 extreme variability
but factors understood

3) How are we addressing the causes of the present uncertainty?

2 • Large-scale direct measurements

3 • Process based phenomenological "model"

4) Do rice fields produce N_2O?

4 yes

Goal: Accurate
Regional – Country – world
Emissions
CH_4, N_2O – Rice Fields $\phi = EF \times G$

Frontiers → CH_4 Vs N_2O relationships (4)

Extrapolation Issues

* Small area flux ~ $0.1 m^2$ – $1 m^2$

(1)

(2) $100 Km^2$ ($f \sim 10^8 - 10^9$)

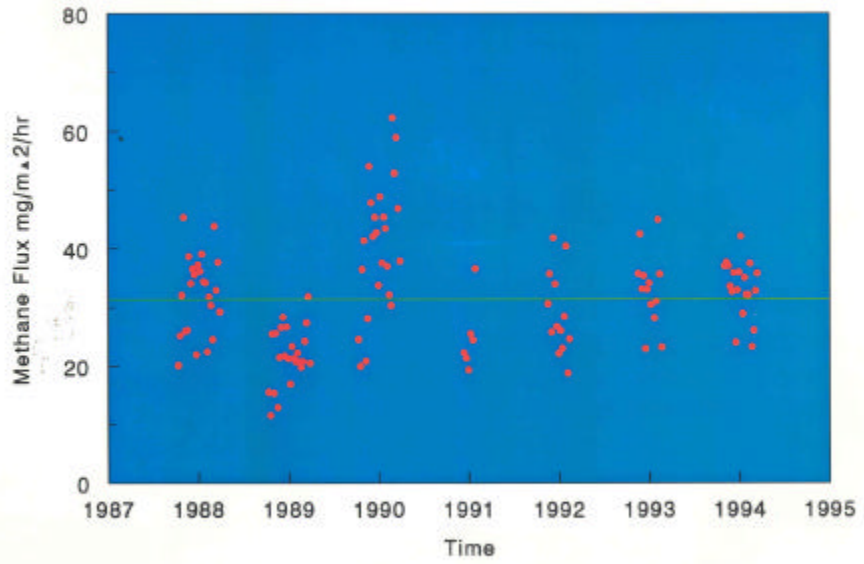
Rapidly Changing Agricultural Practices

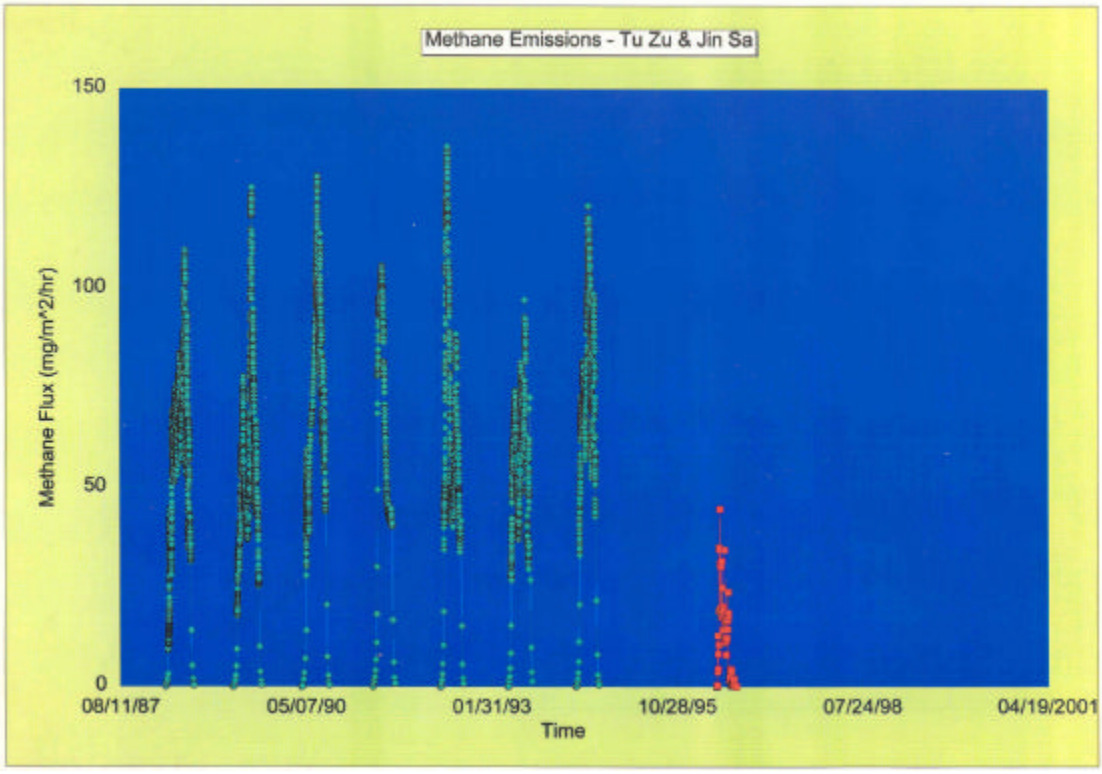
? – 2nd Talk

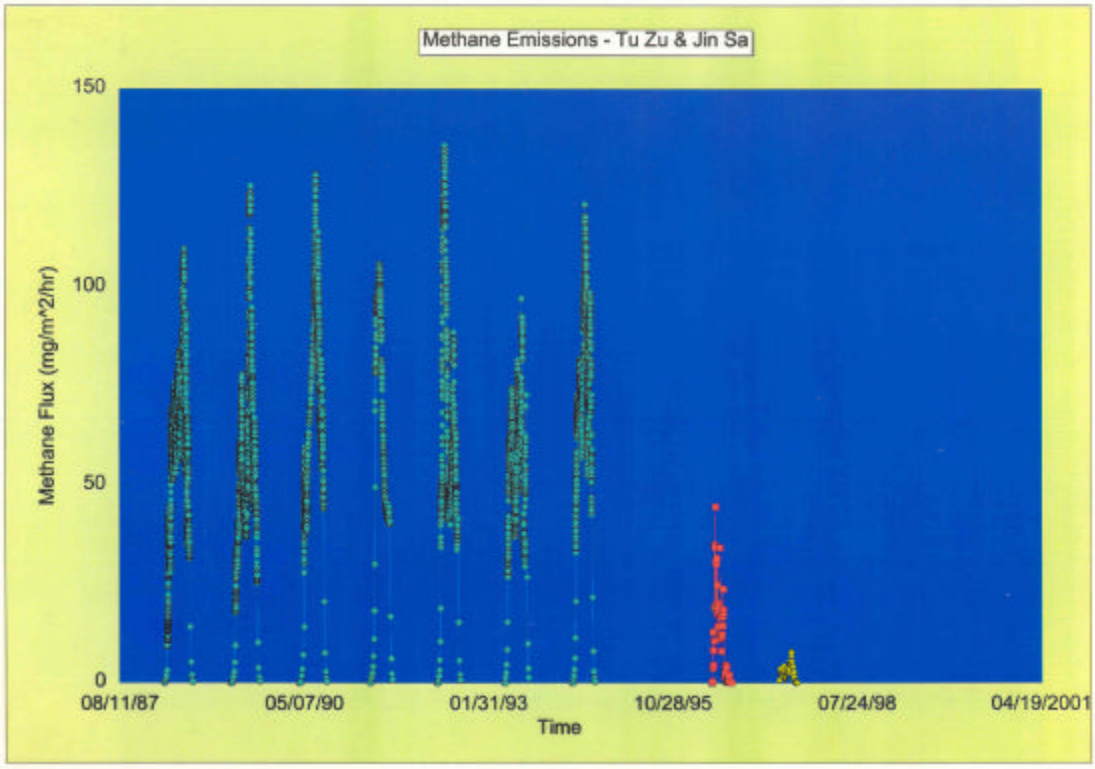
(3) phenomenological model

* Process ~ readily measureable variables

Goal – Regional – Global


80
60
40
20
0
Methane Flux mg/m▲2/hr
1987
1988
1989
1990
1991
1992
1993
1994
1995
Time


Methane Emissions - Tu Zu & Jin Sa
150
100
50
0
Methane Flux (mg/m^2/hr)
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/2001
Time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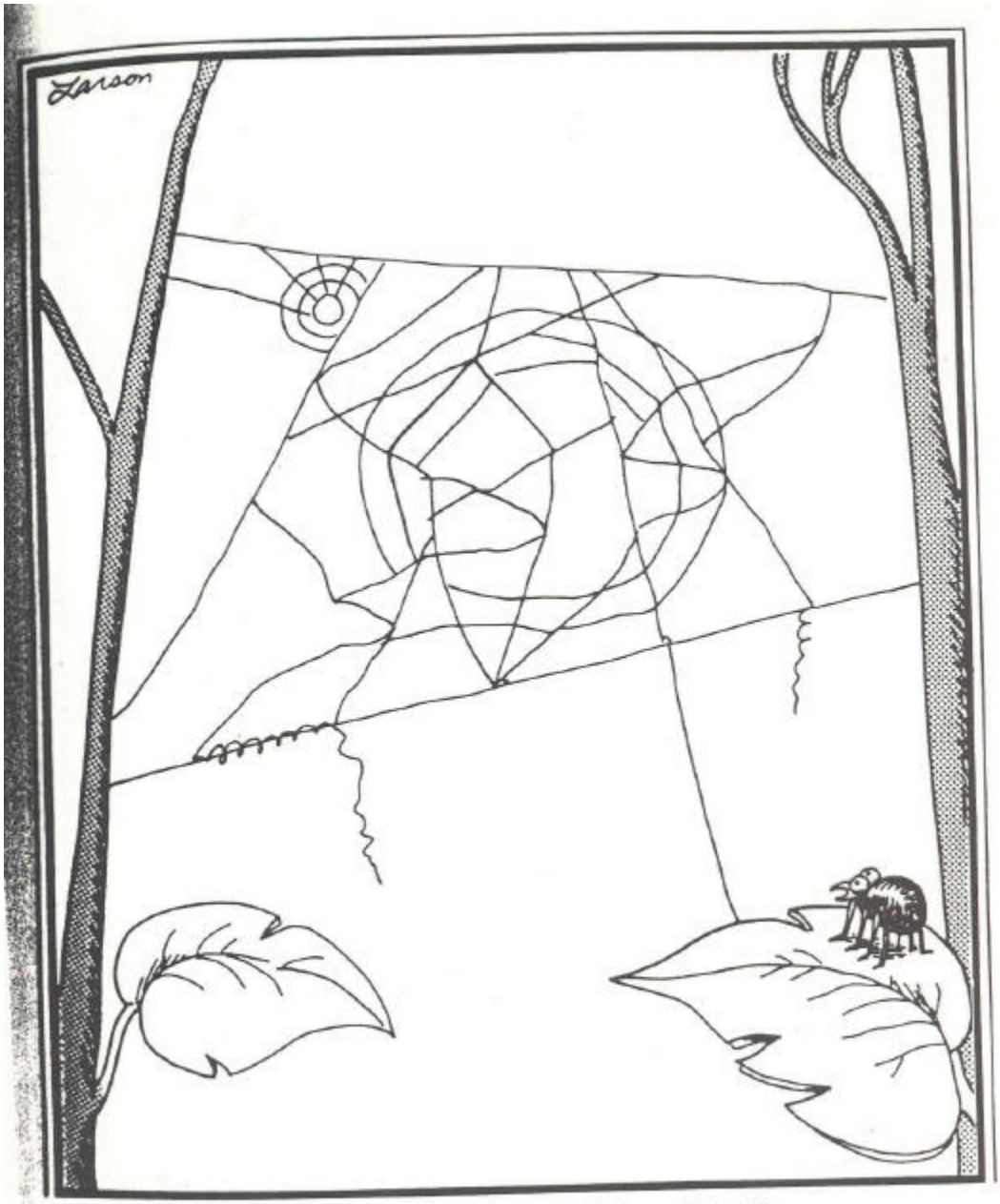
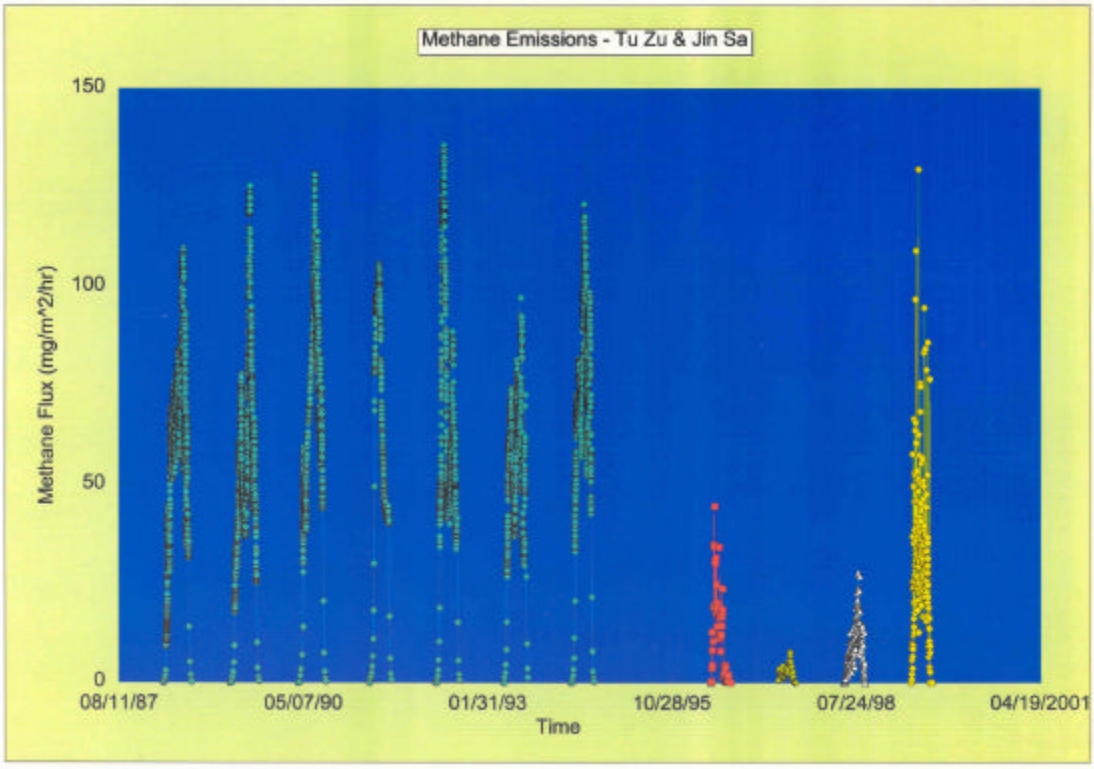
Time



"Whoa! . . . That CAN'T be right!"


Methane Emissions - Tu Zu & Jin Sa
150
100
50
0
Methane Flux (mg/m^2/hr)
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/2001
Time

Methane Emission Measurements

Whole Season - Rice Fields

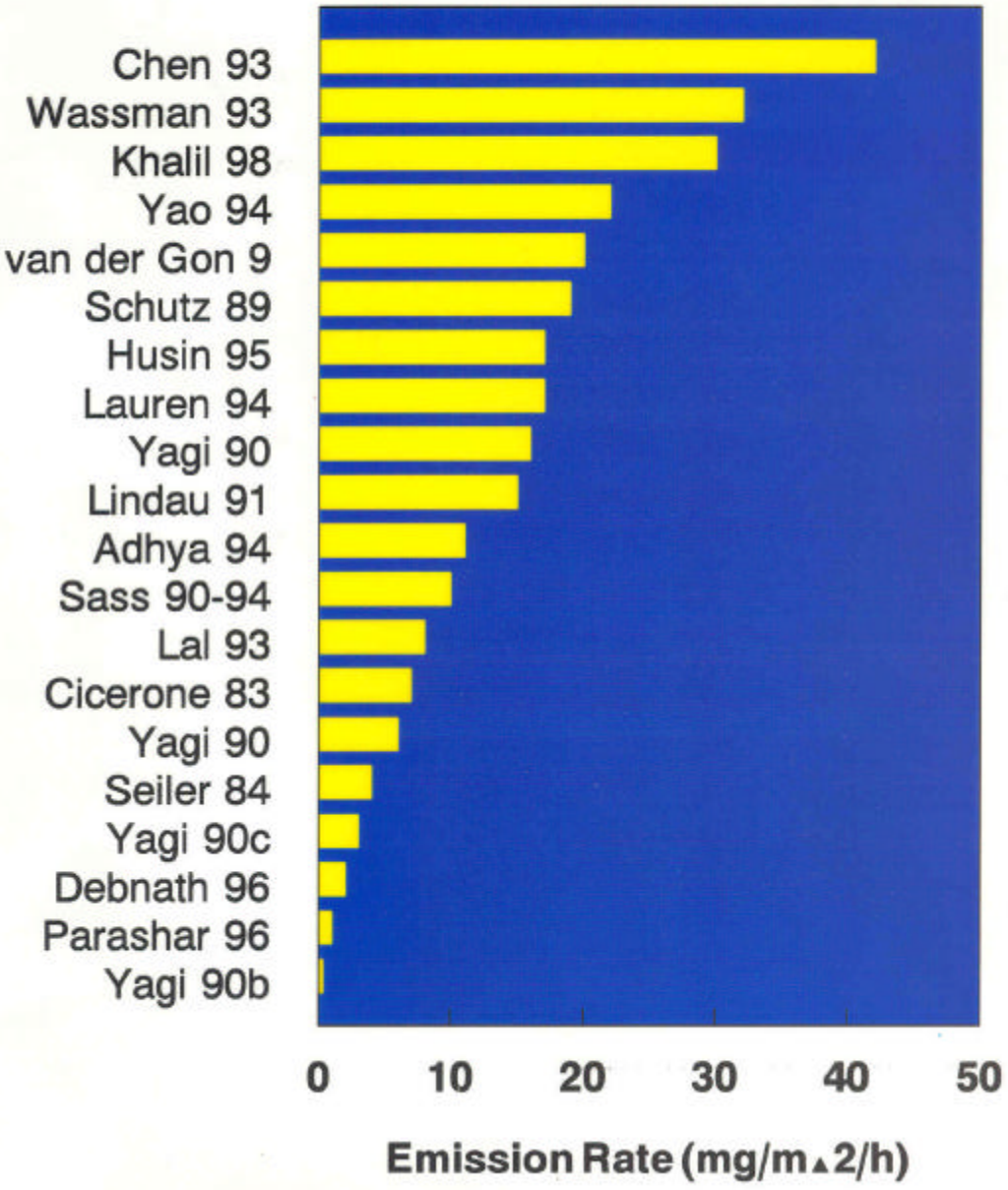


Table 4-8. *Summary of CH_4 Emission Rates (Tg/yr) from Individual Sources*

Type of source	Ehhalt (1974)	Sheppard *et al.* (1982)	Crutzen (1983)	Khalil and Rasmussen (1983)	Seiler (1984)
Domestic animals	101-220	90	60	120	72-99
Rice paddy fields	280	39	30-60	95	30-75
Swamps/marshes	130-260	39	30-220	150	13-57
Ocean/lakes	5.9-45	65	—	23	1-7
Other biogenic	—	817[a]	150[b]	100[c]	6-15
Biomass burning	—	60	30-110	25	53-97
Natural gas leakage		50	20	—	18-29
Coal mining	15.6-49.4	-	—	40	30
Other nonbiogenic	—	50[d]	—	—	1-2[e]
Total source strength	533-854	1210	170-620	553	225-395

[a] From considerations of biomass turnover in natural ecosystems.
[b] Production by termites.
[c] Includes 88 Tg/yr from termites, 12 Tg/yr from tundra.
[d] Fossil-fuel sources other than gas leakage.
[e] Fossil-fuel combustion.

IPCC 1995
60 20-100

10 years ago

5 years ago and Now

Warneck, P
Chemistry of the natural atmosphere (AP, Inc, Ny, 1988)

TABLE 4.7 Estimates of CH_4 Emission Rates (Tg year $^{-1}$) from Individual Sources

Type of source	Ehhalt (1974)	Bolle *et al.* (1986)	Cicerone and Oremland (1988)	Khalil and Shearer (1993)
Ruminants etc.	101–220	70–100	80 (65–100)	55–90
Termites	—	2–5	40 (10–100)	15–35
Rice paddy fields	280	70–170	110 (60–170)	55–90
Natural wetlands	130–260	25–70	115 (100–200)	110
Tundra	—	2–15	5	
Ocean	6–45	1–7	15 (2–20)	4
Domestic sewage	—	—	—	27–80
Landfills	—	10	40 (30–70)	11–32
Animal waste	—	—	—	20–30
Coal mining	15–50	35	35 (25–45)	25–50
Natural gas leakage	—	30–40	45 (25–45)	30
Biomass burning	—	55–100	55 (50–100)	50
Total	533–854	300–552	540 (370–855)	402–601

Warneck Chemistry of the Natural Atmosphere Academic Press 2nd Edition, 1999

Present ~20 – 100 Tg/y

Critical Factors

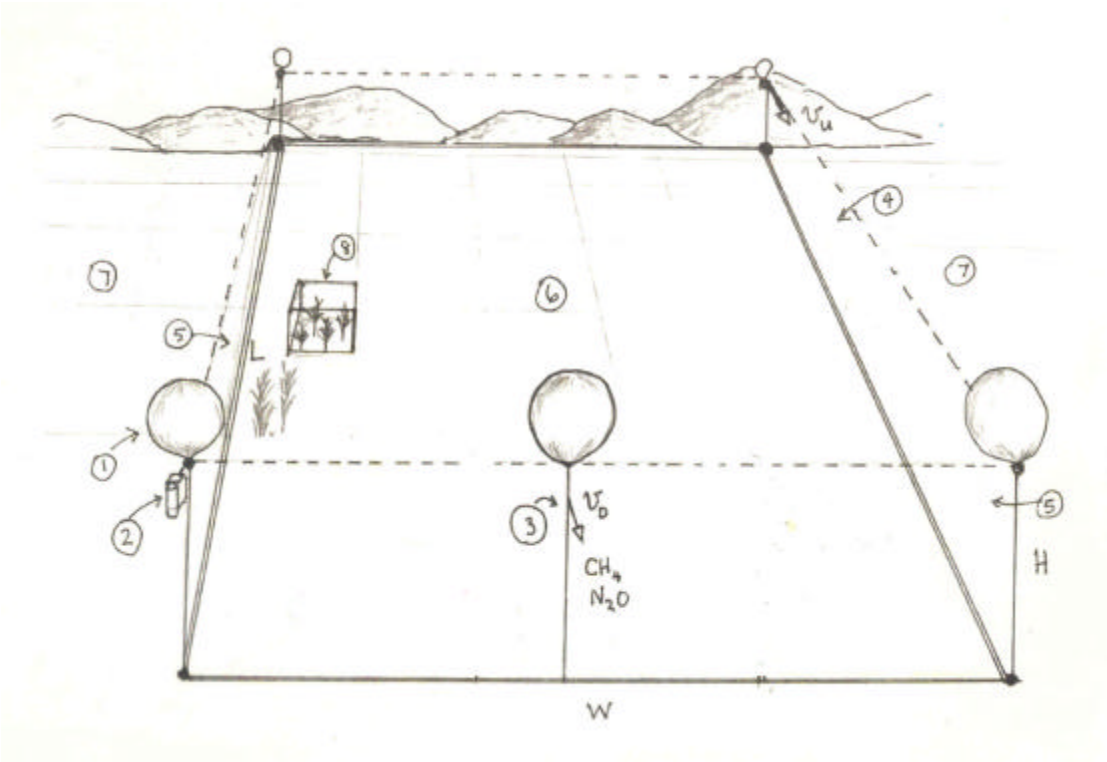
* Water (management)
* Fertilizer

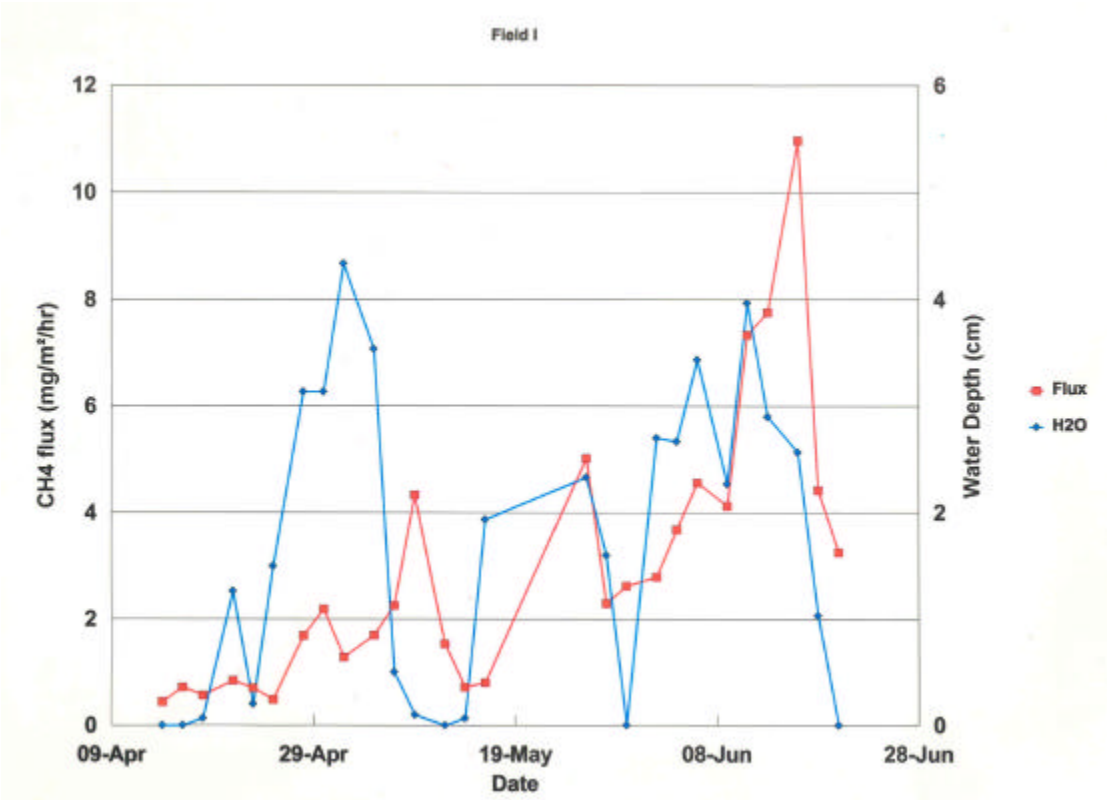
  Organic
  N_2 Based
* Oxidation (in root zone)

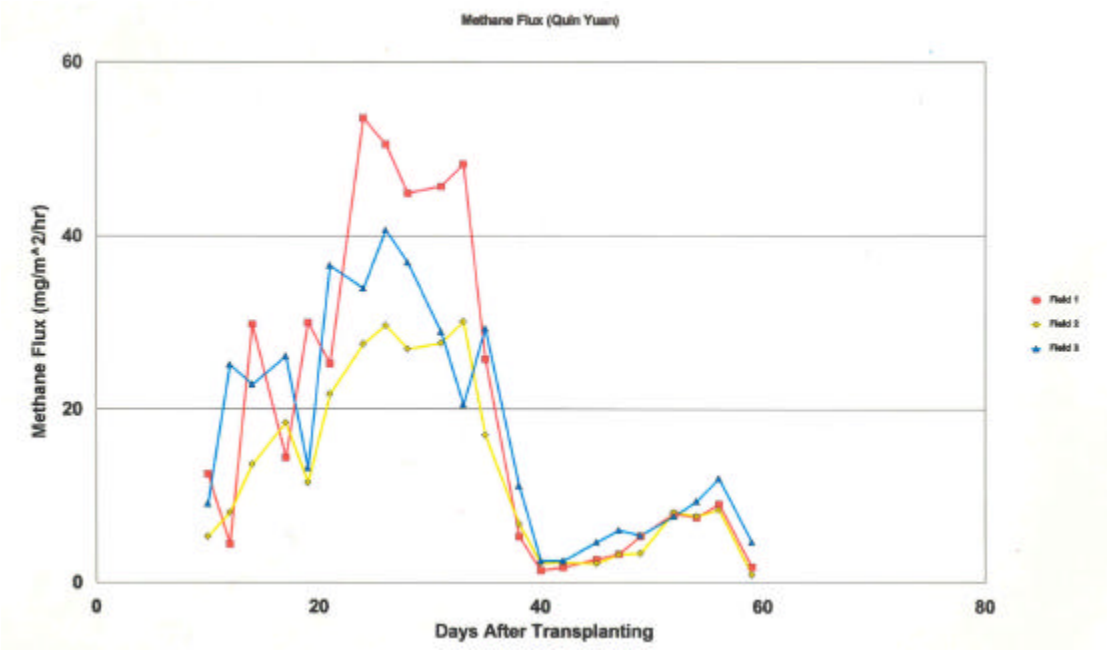
  ~ 80-90% ⇒ Factor of 2 in Flux with same Production

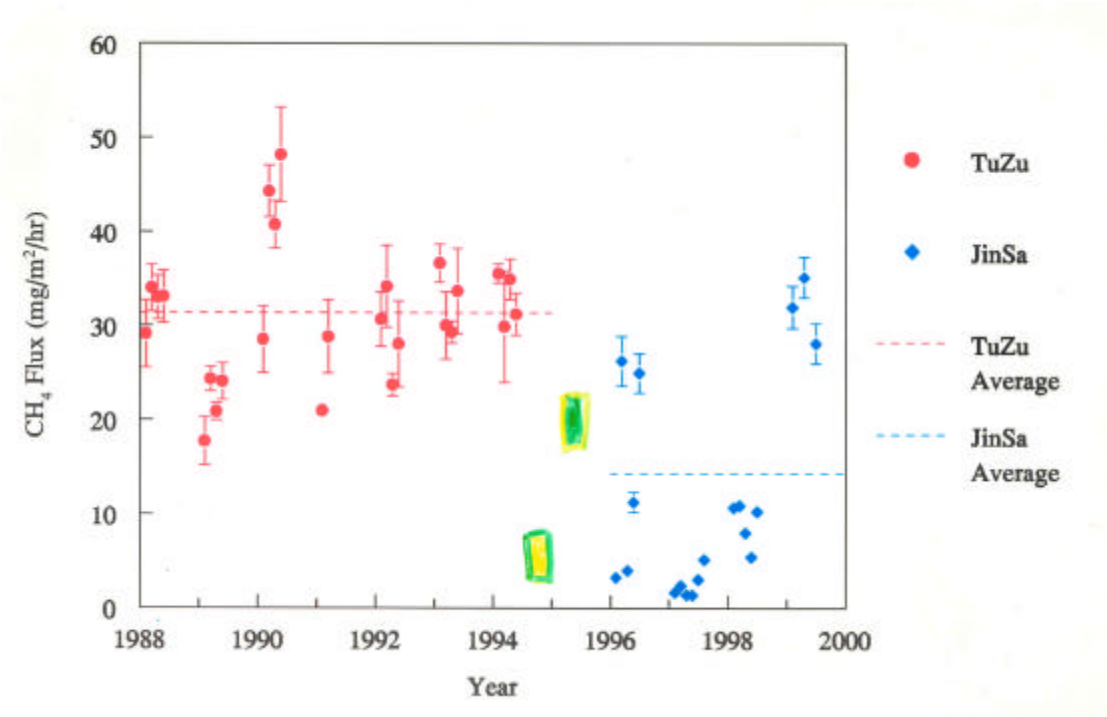
Many others

* Soil properties
* cultivar
* Soil temperature
* Met. Variables – wind...
* rain
* microbiology

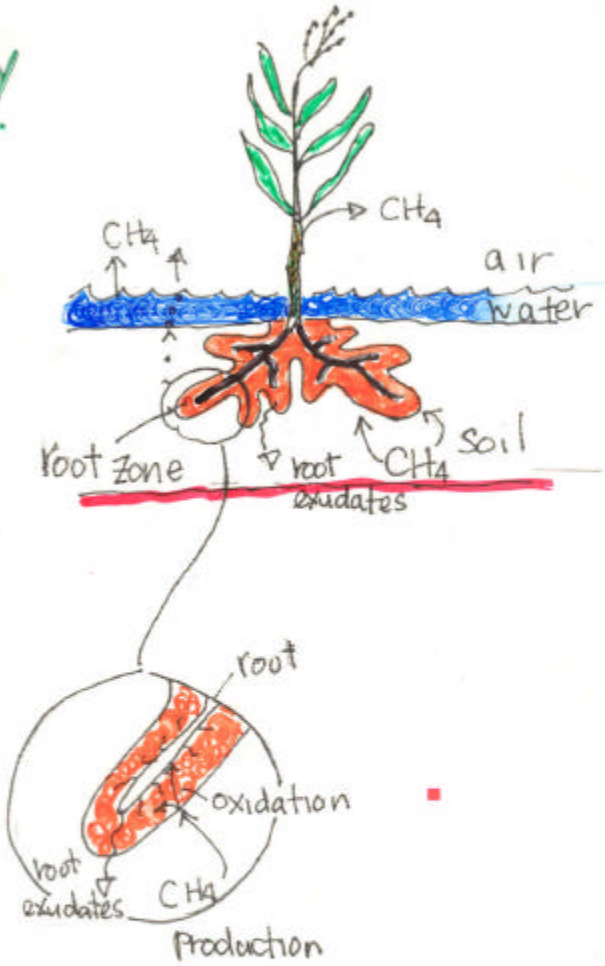

L
H
W
v_u
v_D
CH_4
N_2O


Field I
CH4 flux (mg/m²/hr)
Water Depth (cm)
Date
09-Apr
29-Apr
19-May
08-Jun
28-Jun
Flux
H2O


Methane Flux (Quin Yuan)
Methane Flux (mg/m^2/hr)
Days After Transplanting
0
20
40
60
80

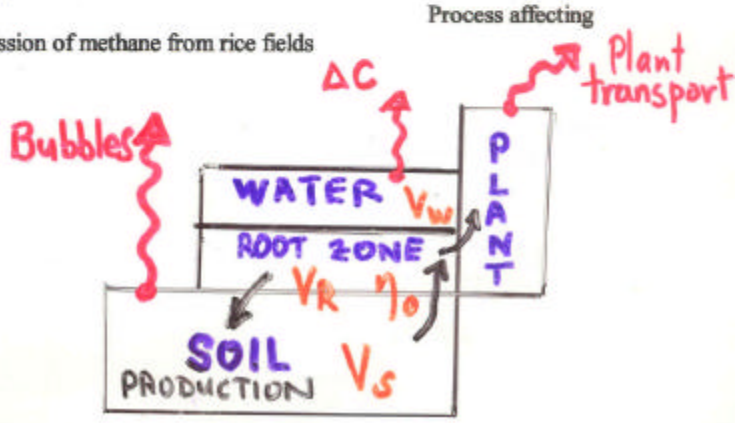

CH_4 Flux (mg/m^2/hr)
Year
1988
1990
1992
1994
1996
1998
2000
TuZu
JinSa
TuZu Average
JinSa Average

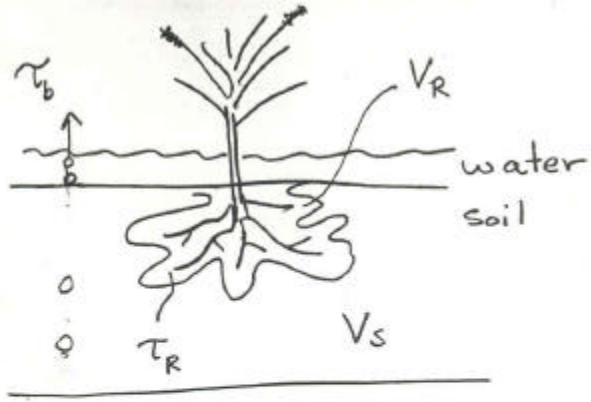
Theory



the production, oxidation and emission of methane from rice fields

Process affecting





Soil : $$\frac{d}{dt} C_s(N,t) = P(N,t) - \frac{1}{\tau_s}\left[C_s(N,t) - C_R(N,t)\right]$$

Rhizosphere: $$\frac{d}{dt} C_R(N,t) = \frac{1}{\tau_s}\left[C_s(N,t) - C_R(N,t)\right]\frac{\delta_s}{\delta_R(N)} - \left[\frac{1}{\tau_o} + \frac{1}{\tau_p(N,t)}\right] C_R(N,t)$$

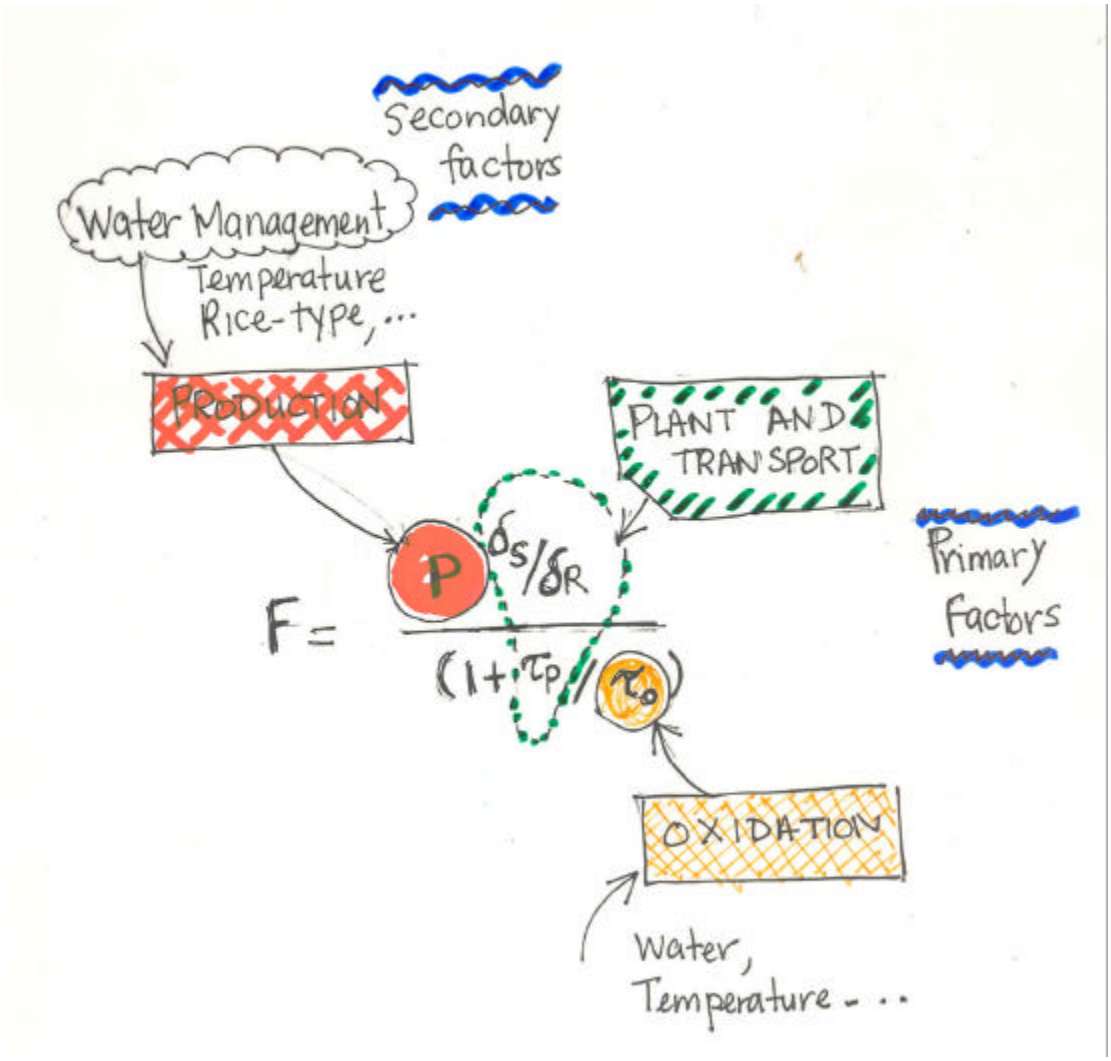
$$\boxed{\text{Flux} = \frac{1}{\tau_p} C_R(N,t)}$$

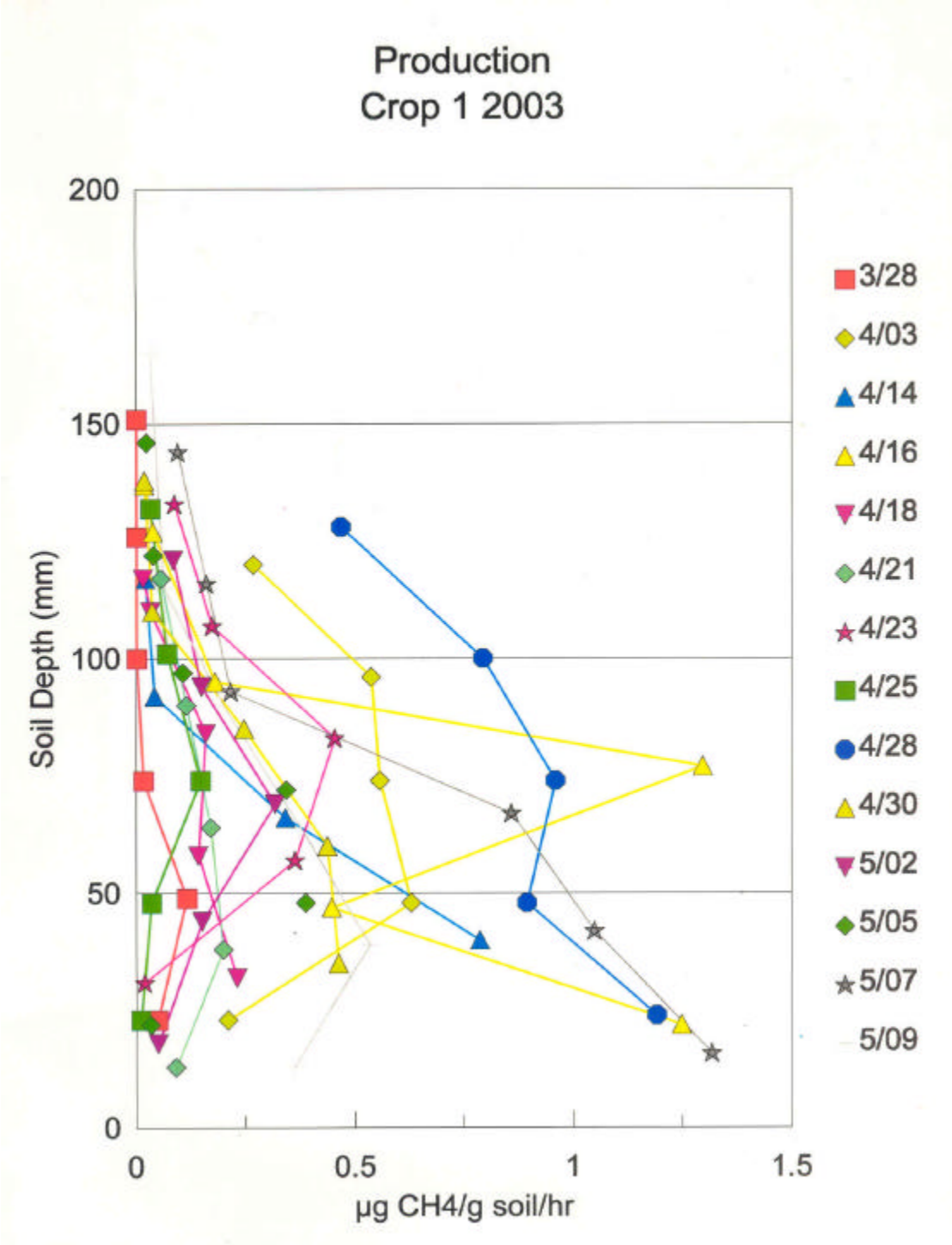
Symbols

N = #Plants/area
δ = effective depths
P = Production of CH_4
C = Concentrations

Characteristic Times

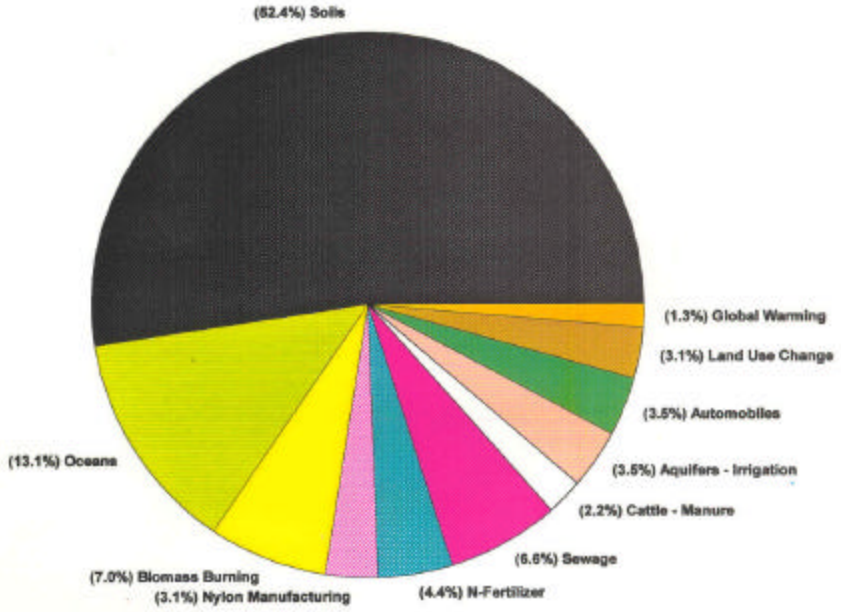
τ_s = exchange: soil → rhizosphere
τ_o = Oxidation lifetime
τ_p = exchange: root → plant

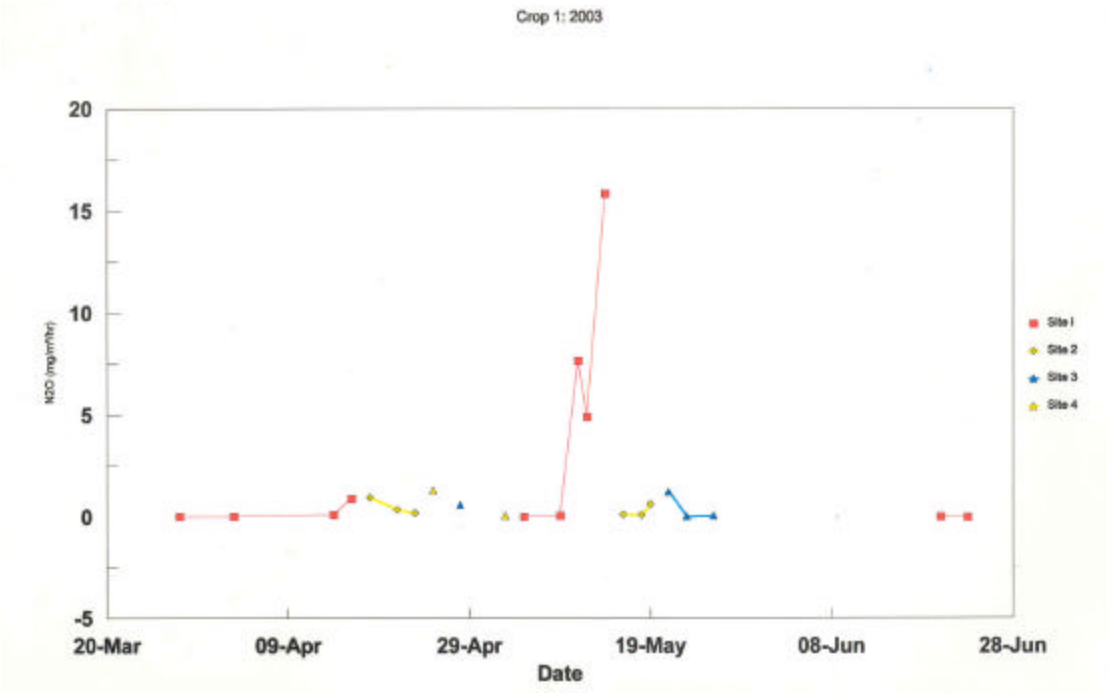

Secondary factors
Water Management
Temperature
Rice-type, ...
PRODUCTION
PLANT AND TRANSPORT
Primary Factors
P
δs/δR
F =
(1+τp/τo)
OXIDATION
Water,
Temperature ...


Production
Crop 1 2003
Soil Depth (mm)
200
150
100
50
0
0
0.5
1
1.5
µg CH4/g soil/hr
3/28
4/03
4/14
4/16
4/18
4/21
4/23
4/25
4/28
4/30
5/02
5/05
5/07
5/09

N2O - Nitrous Oxide

Source	Emissions (Tg/yr) Natural	Man-Made (Very Uncertain)
Soils	12	
Oceans	3	
Biomass Burning		1.6
Nylon Manufacturing		0.7
N-Fertilizer		1.0
Sewage		1.5
Cattle - Manure		0.5
Aquifers - Irrigation		0.8
Automobiles		0.8
Land Use Change		0.7
Atmospheric Formation		?
Global Warming		0.3
TOTALS	15	8
GRAND TOTAL	23	Tg/yr





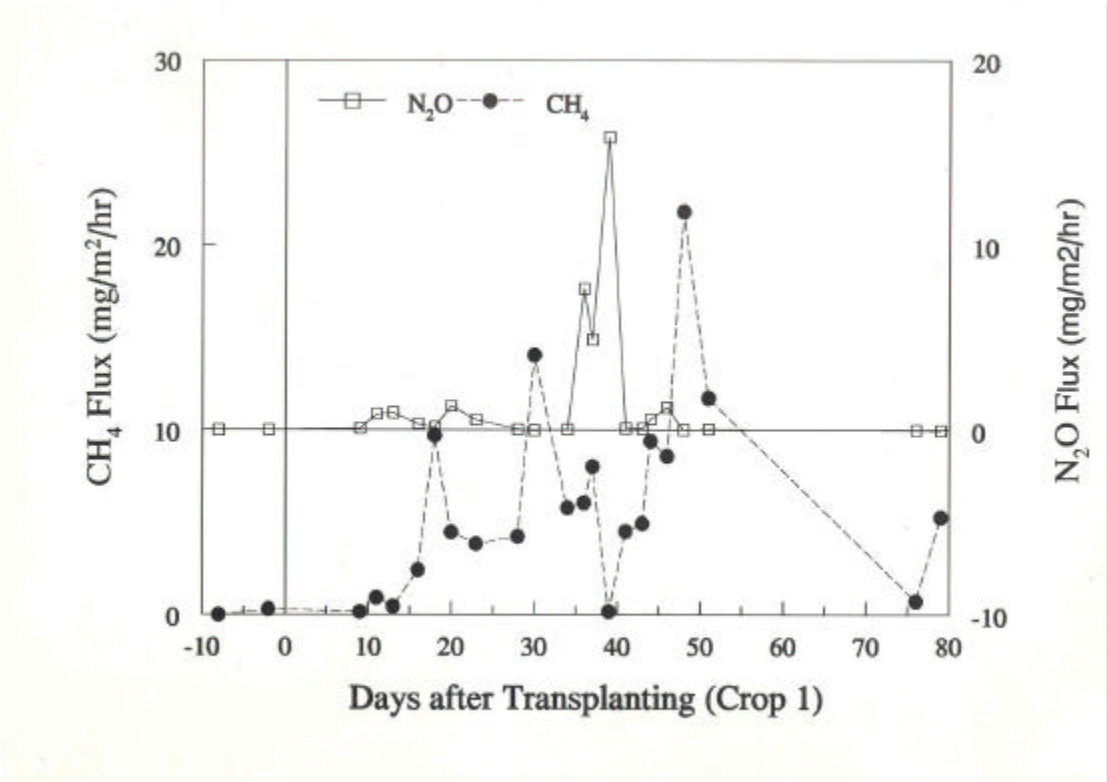


Figure 8. Methane flux vs. Nitrous oxide flux from rice fields near Qing Yuan, Guangzhou Province.

Conclusions

1. We have learned a lot about how much methane is emitted from rice plants, and the processes that control it.

2. We cannot translate this knowledge reliably to country-wide or global scales

our new experiments are designed to address this issue
- ✓ Box Flux
- ✓ soil /oxid
- ✗ Balloon – trial only

3. There is (probably) an inverse relationship between CH_4 and N_2O emissions

our experiments are aimed towards delineating this relationship and hence the trade offs for controling CH_4 emissions from rice fields
- ✓ Box Flux
- ✗ Balloon
- ✗ Soil