Decadal Trends in Methane Emissions From Rice Fields in China

M.A.K.Khalil
M.J.Shearer
Department of Physics
Portland State University
Portland, Oregon, USA

R.A.Rasmussen
R.W.Dalluge
Oregon Graduate Institute
Beaverton, Oregon, USA

C.Duan
L.Ren
Chinese Academy of Sciences, PRC

DOE/CAS Science Team Meeting
Beijing, PRC October 27-30, 2003

Outline

1. Methane Cycle Overview

- ☞ Global Methane Concentrations & Trends
- ☞ Role of Rice Agriculture

2. Emission Factor Foundations: China and World

- ☞ Rice Hectares Harvested
- ☞ Fertilizer Use

3. Changing Agricultural Practices

- ☞ The Sichuan Interviews

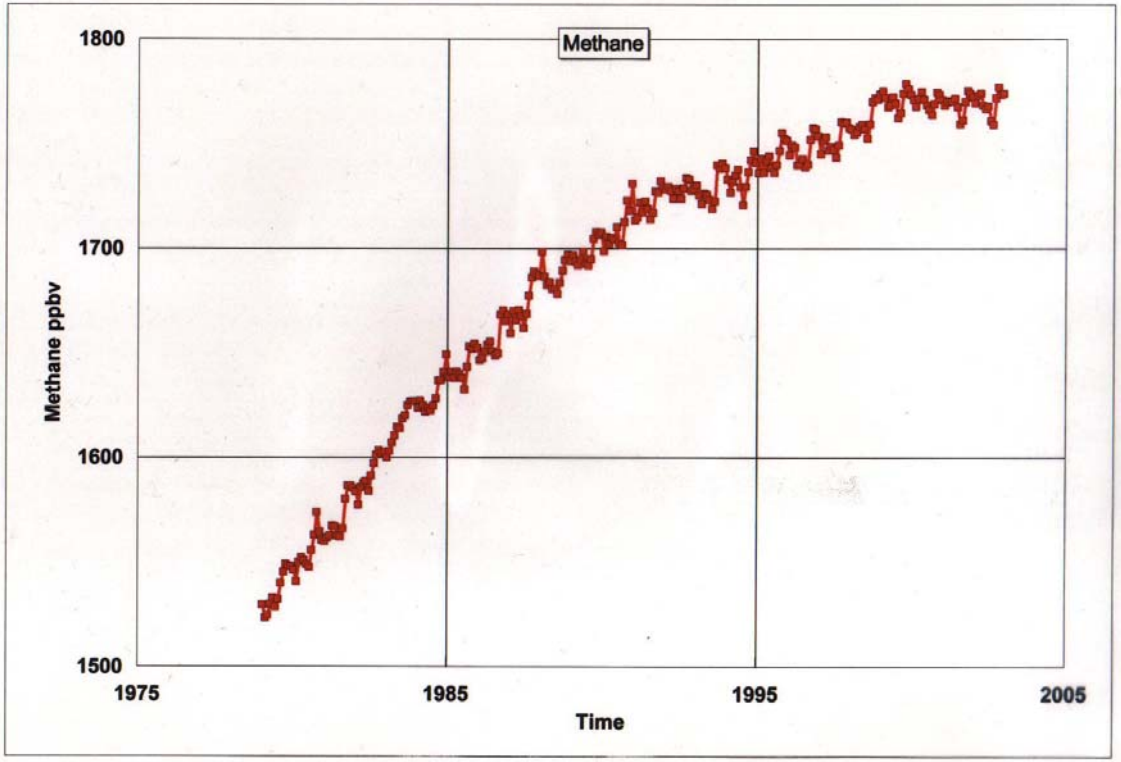
Time Series of Emission Factors

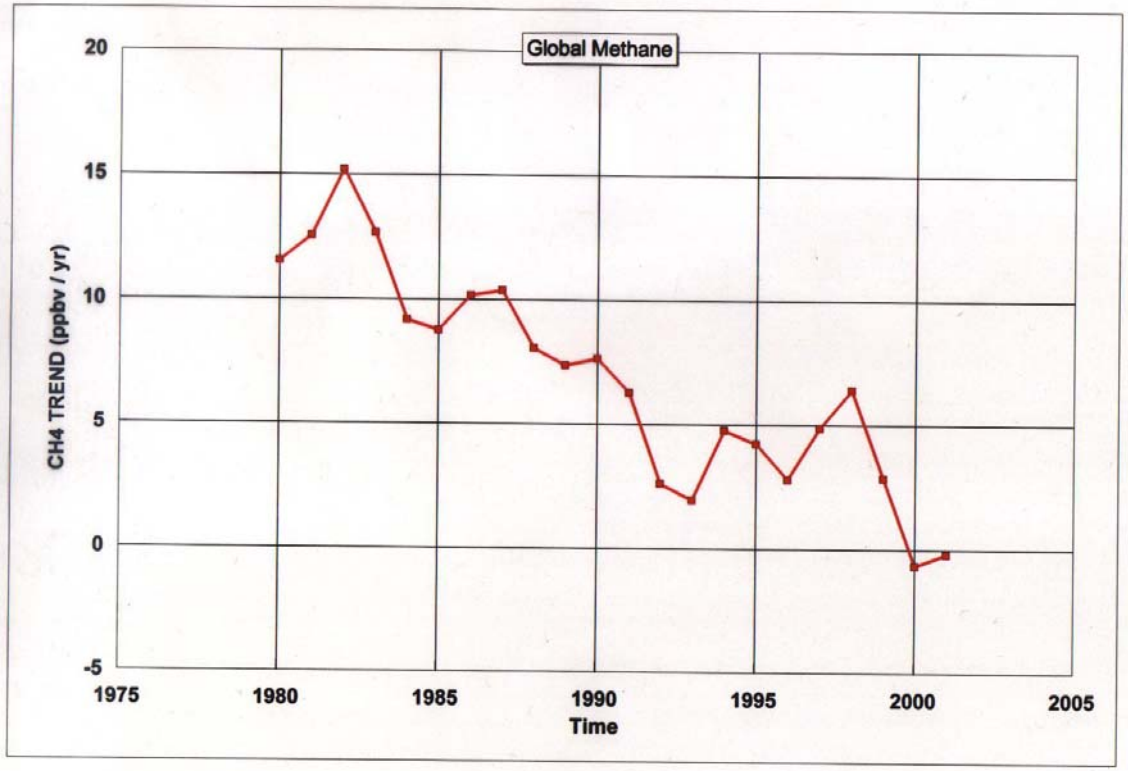
- ☞ N-Fertilizer effect
- ☞ Water effect

4. Estimates of methane emissions - China (last century)

- ☞ No adjustment for emission factor change
- ☞ With emission factor adjustment

5. Conclusions


Methane
1800
1700
1600
1500
Methane ppbv
1975
1985
1995
2005
Time


Global Methane
CH4 TREND (ppbv / yr)
20
15
10
5
0
-5
1975
1980
1985
1990
1995
2000
2005
Time

CH4 - Methane

Source	Emissions (Tg/yr) Natural	Man-Made
Wetlands	110	
Termites	20	
Ocean	4	
Geological	10	
Fires	2	
Rice Agriculture		65
Animals (Cattle)		79
Manure		15
Landfills		22
Waste Water Treatment		25
Biomass Burning		50
Coal Mining		46
Natural Gas Leakage		30
Low Temperature Fuels		17
Other		13
TOTALS	150	360
GRAND TOTAL	510	Tg/yr

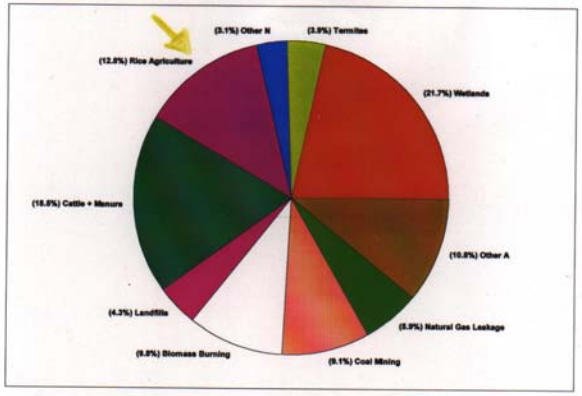
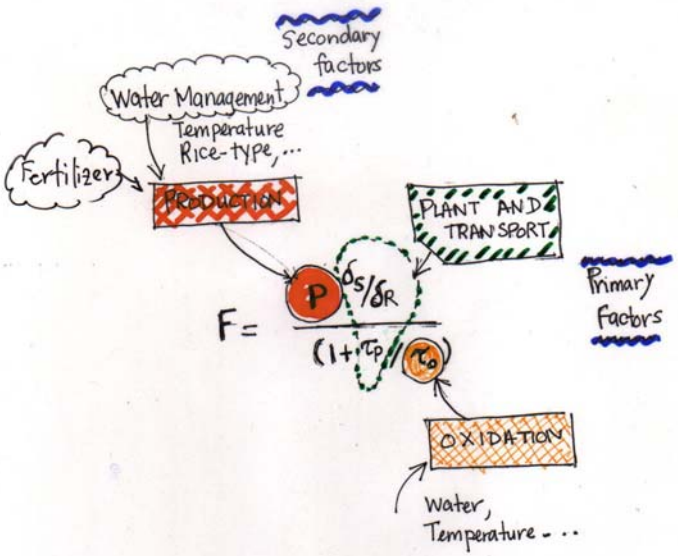


TABLE 4.7 Estimates of CH_4 Emission Rates (Tg year $^{-1}$) from Individual Sources

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

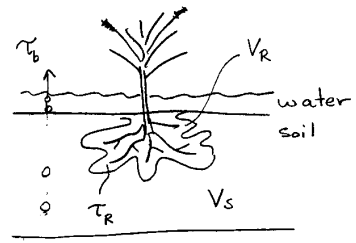
Present ~20 – 100 Tg/y



$$F_{Tot} = \int_A F(a)\, da$$

Total Area

Flux from a



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

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

<u>Symbols</u>

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

<u>Characteristic Times</u>

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

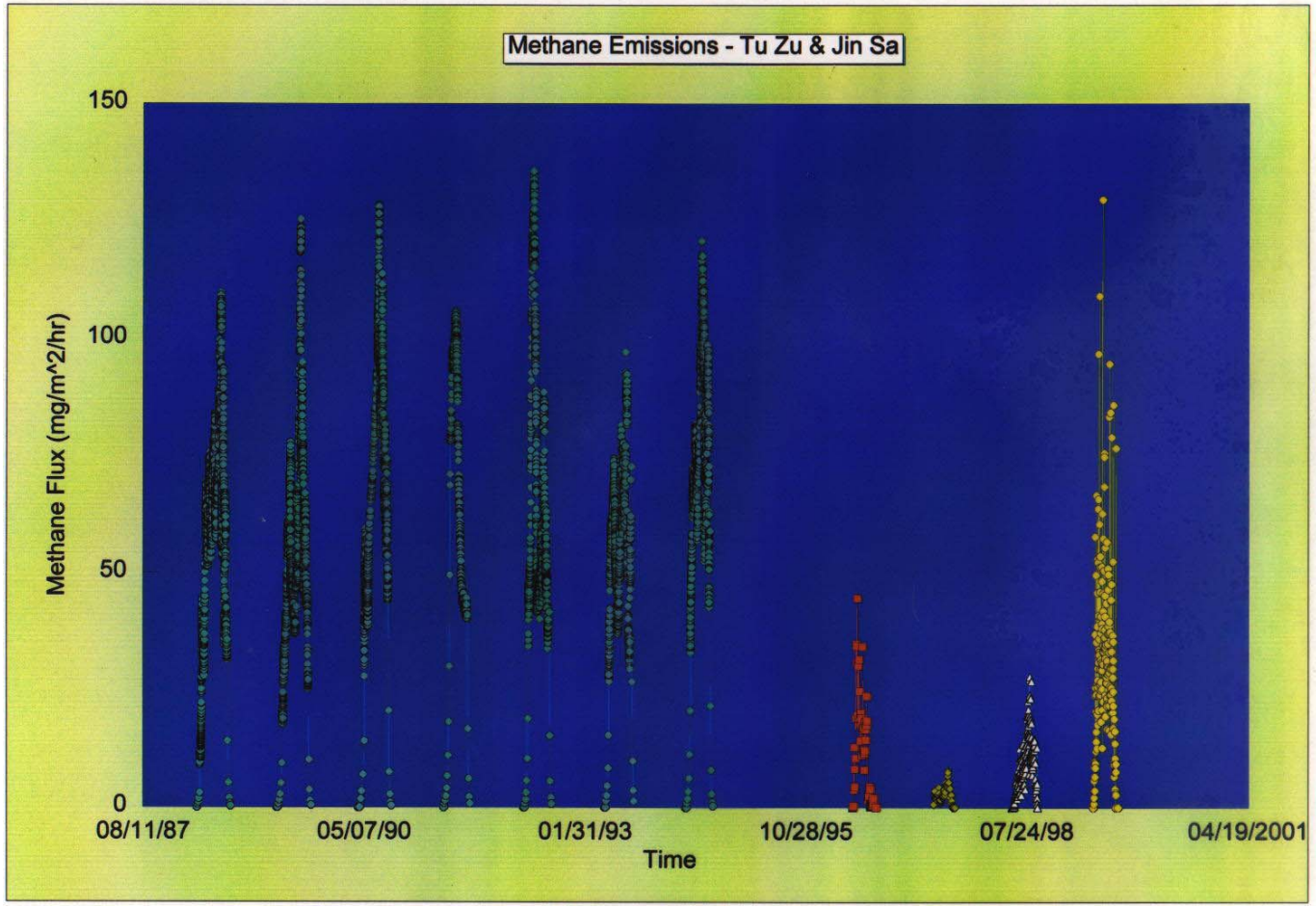
Critical Factors

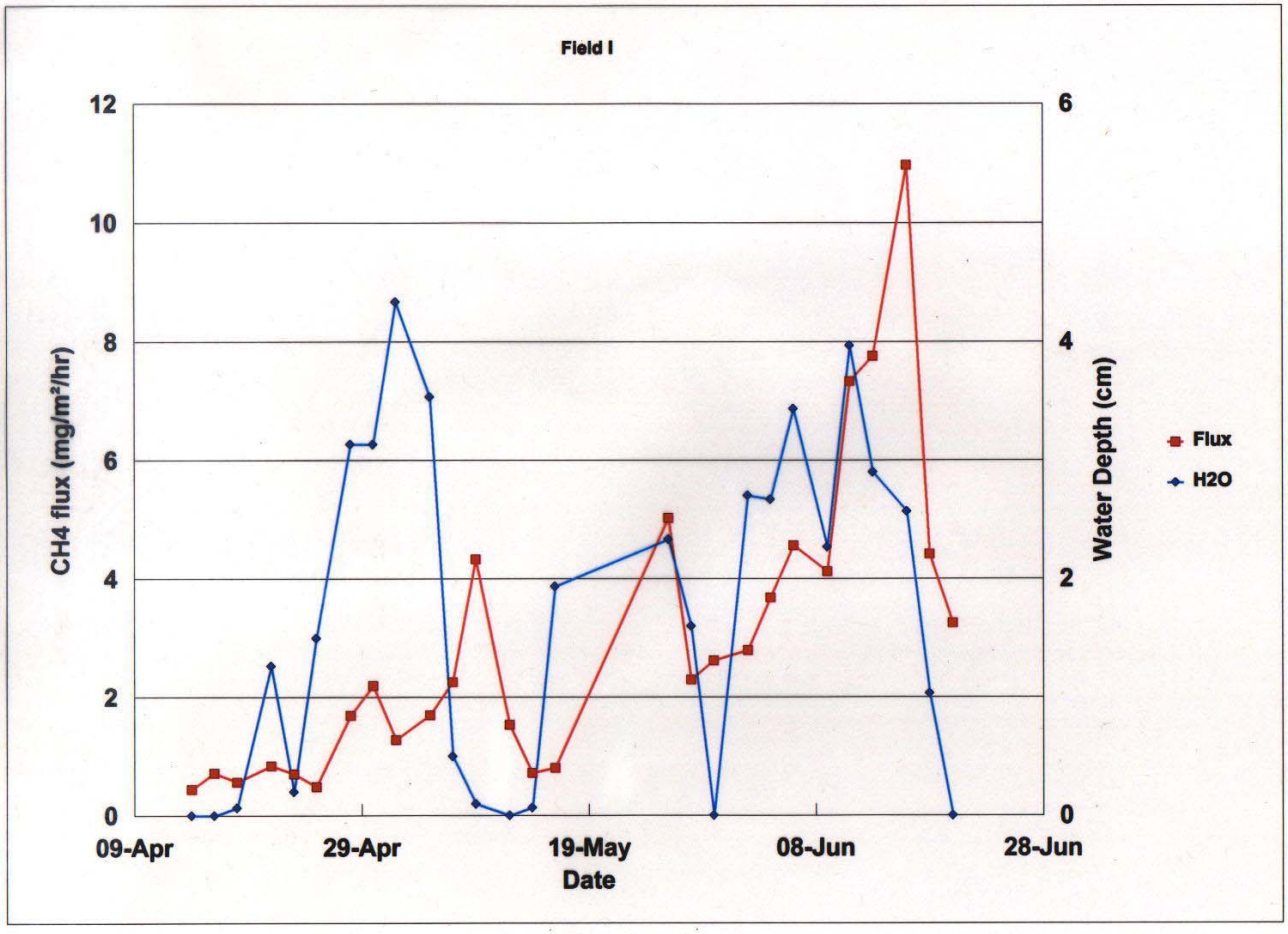
* Water (management)
* Fertilizer
  - Organic
  - N_2 Based
* Oxidation (in root zone)
  - ~ 80-90% ⇒ Factor of 2 in Flux with same production

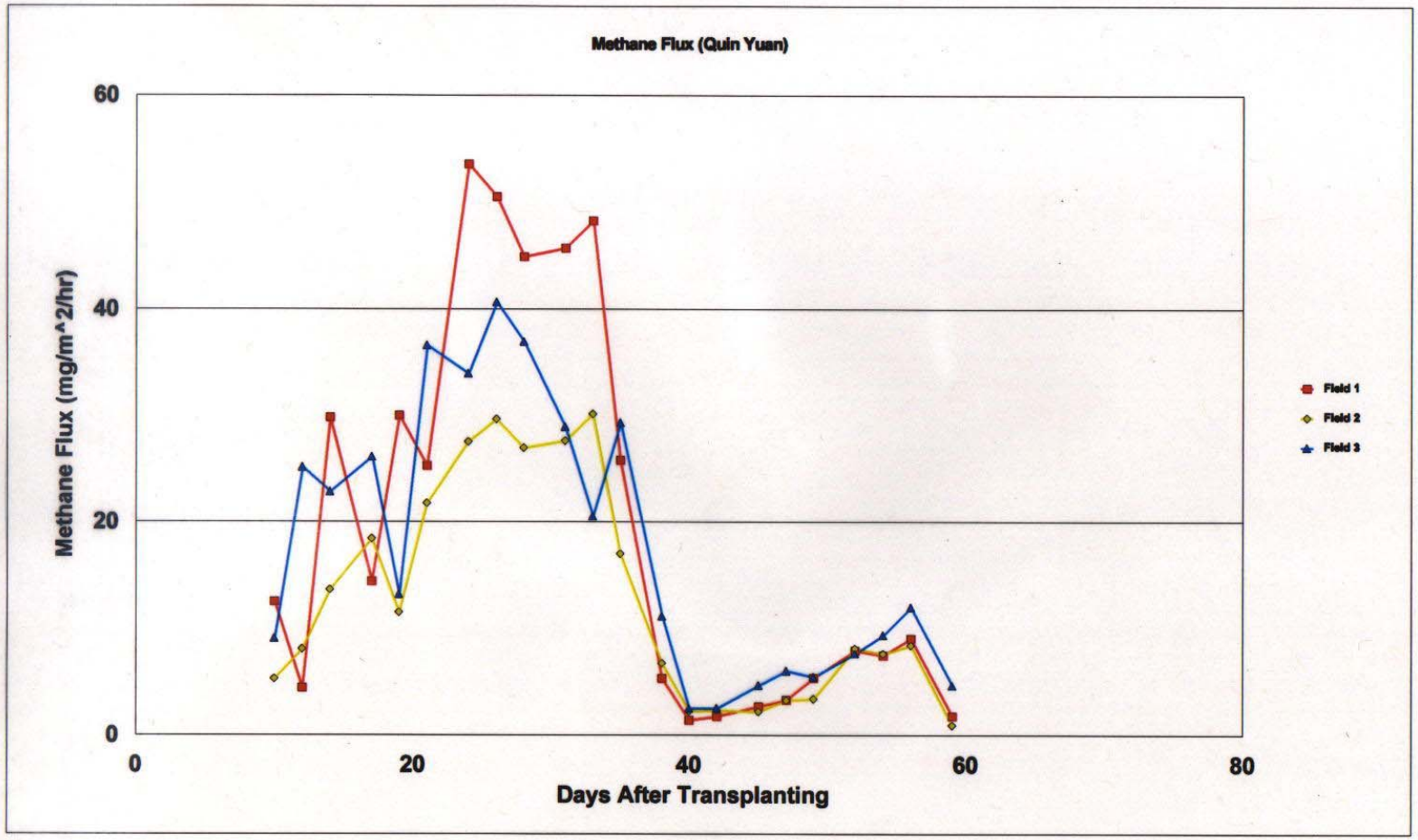
Many others

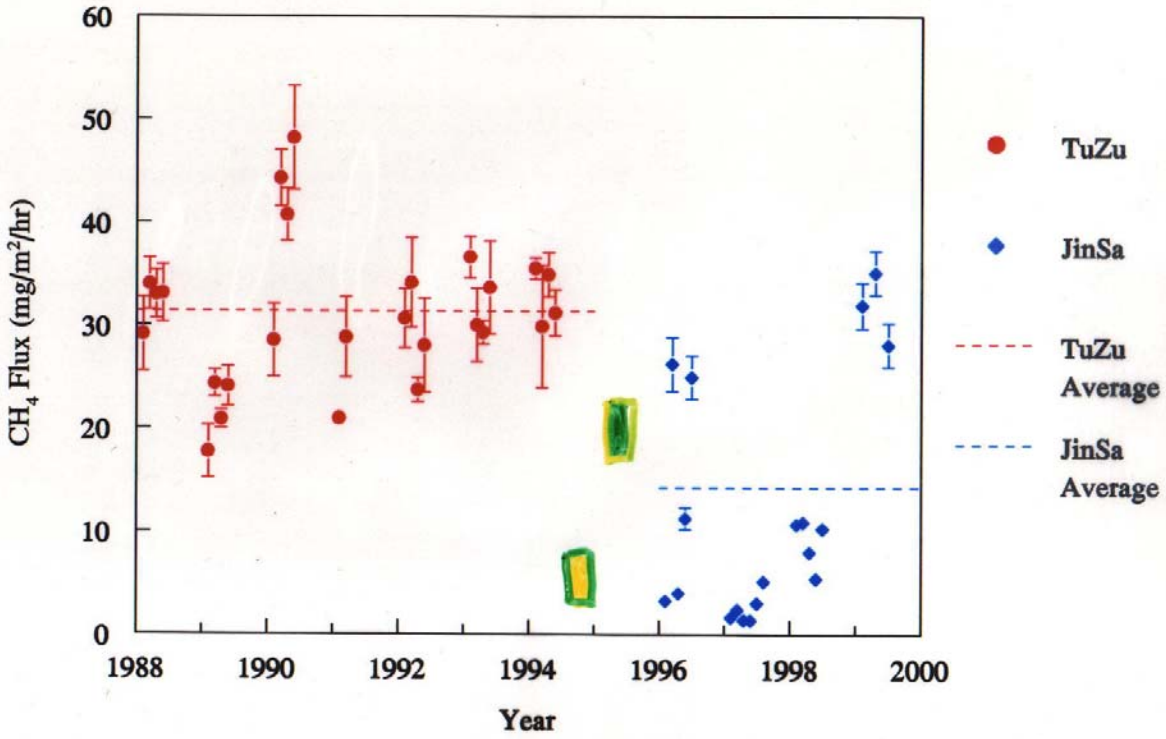
* Soil properties
* cultivar
* Soil temperature
* Met. Variables – wind...
* rain
* microbiology

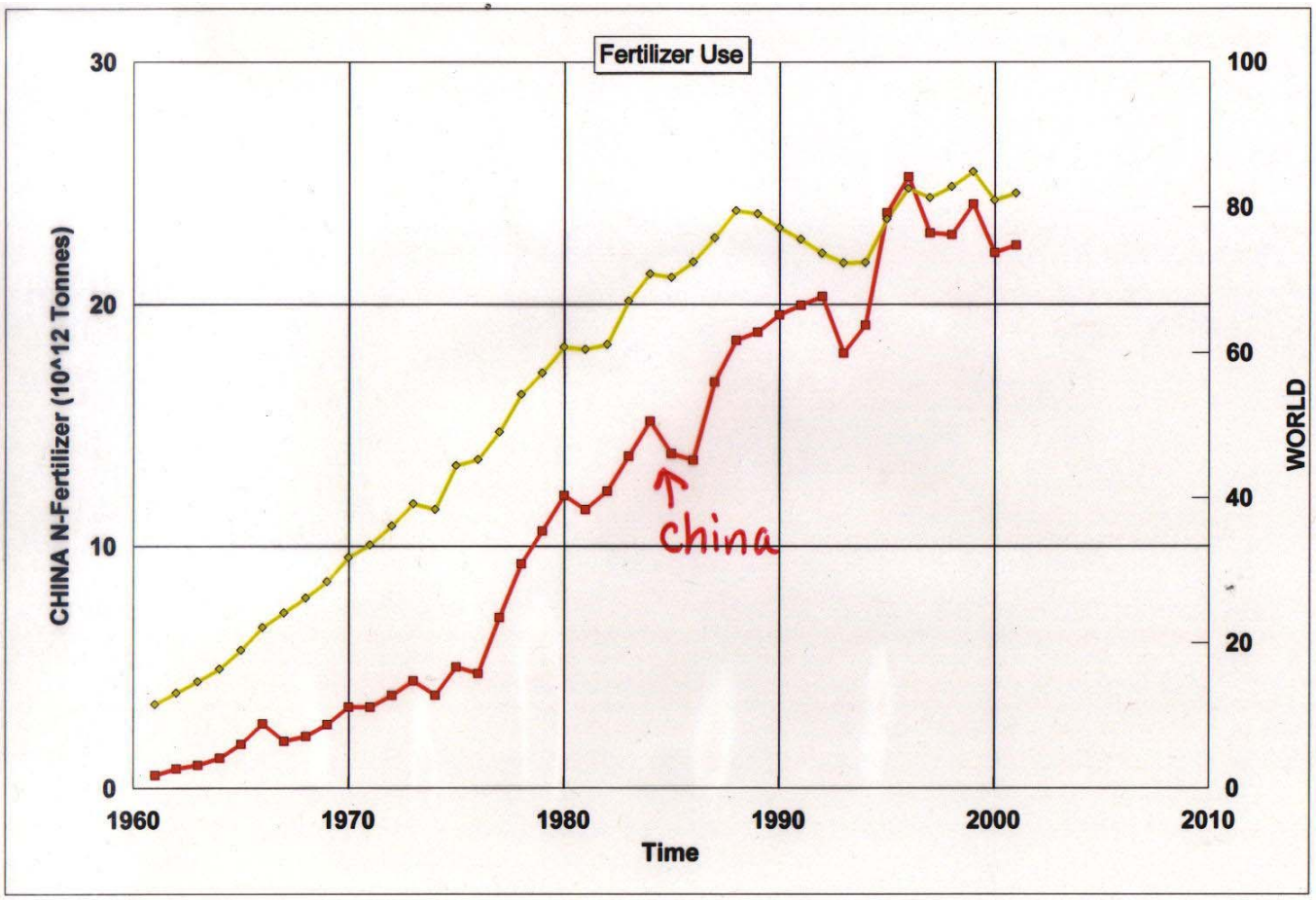
23 11:07 AM

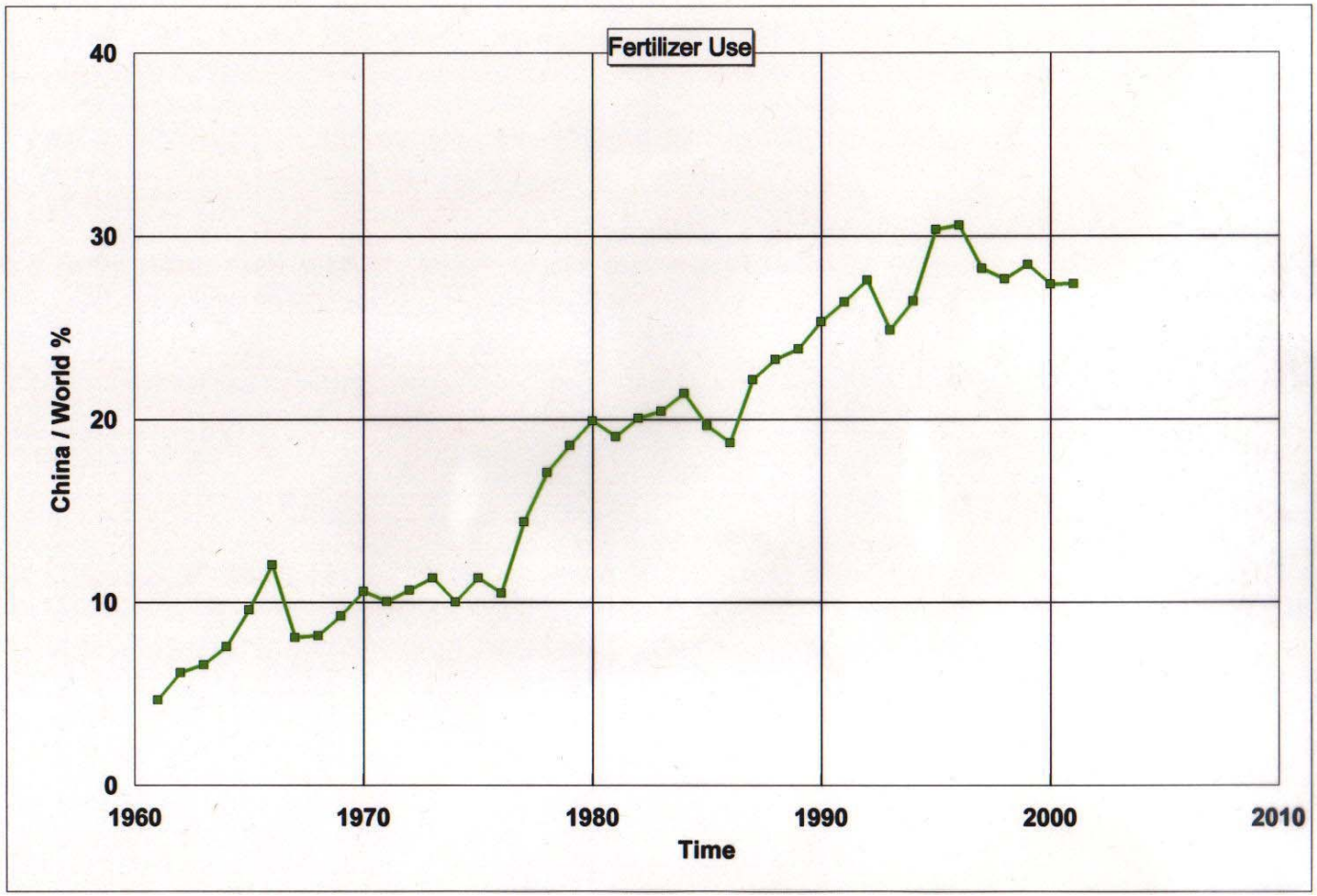

Methane Emissions - Tu Zu & Jin Sa
150
100
50
0
Methane Flux (mg/m^2/hr)
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/2001
Time

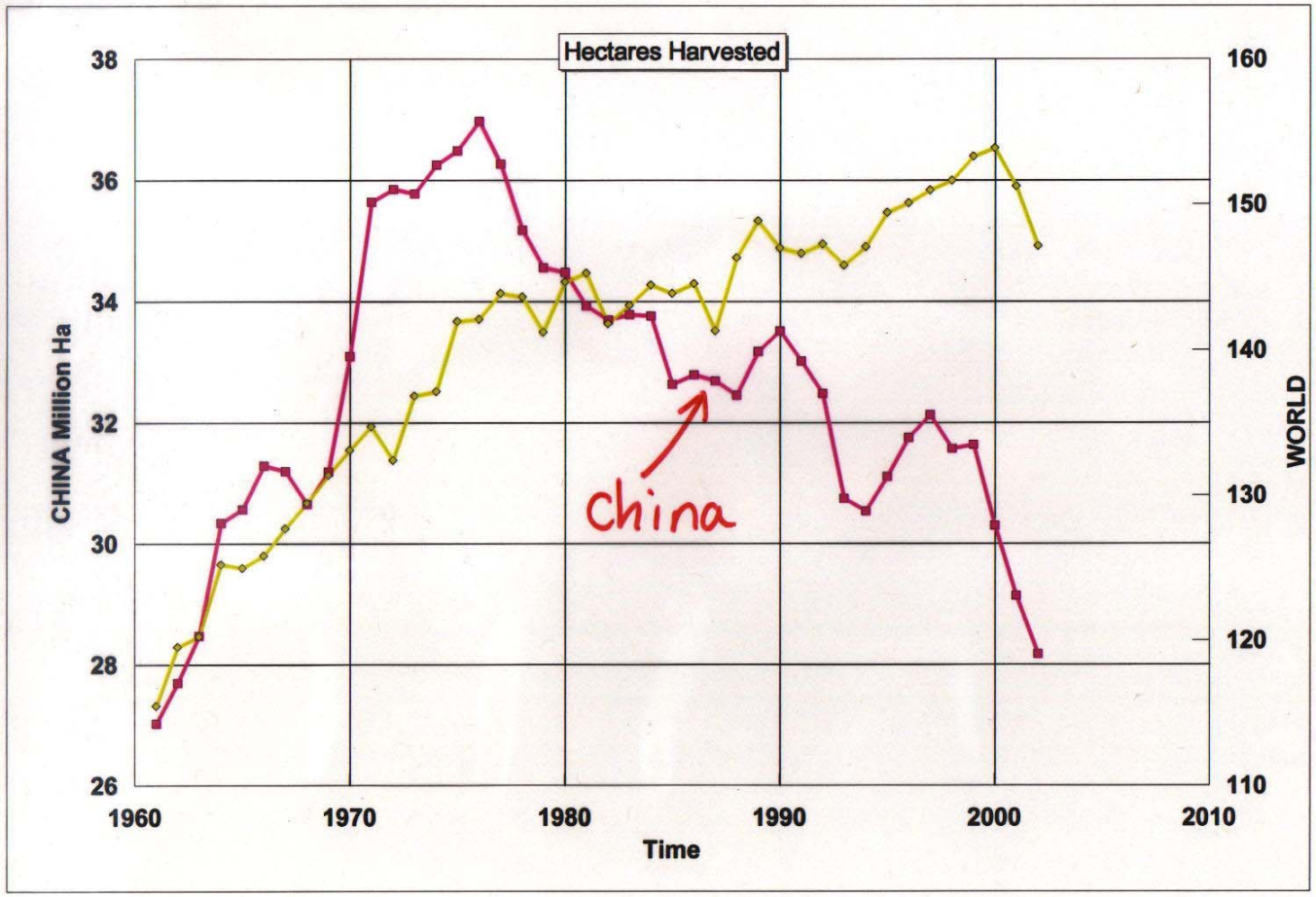

Field I
12
10
8
6
4
2
0
CH4 flux (mg/m²/hr)
6
4
2
0
Water Depth (cm)
09-Apr
29-Apr
19-May
08-Jun
28-Jun
Date
Flux
H2O

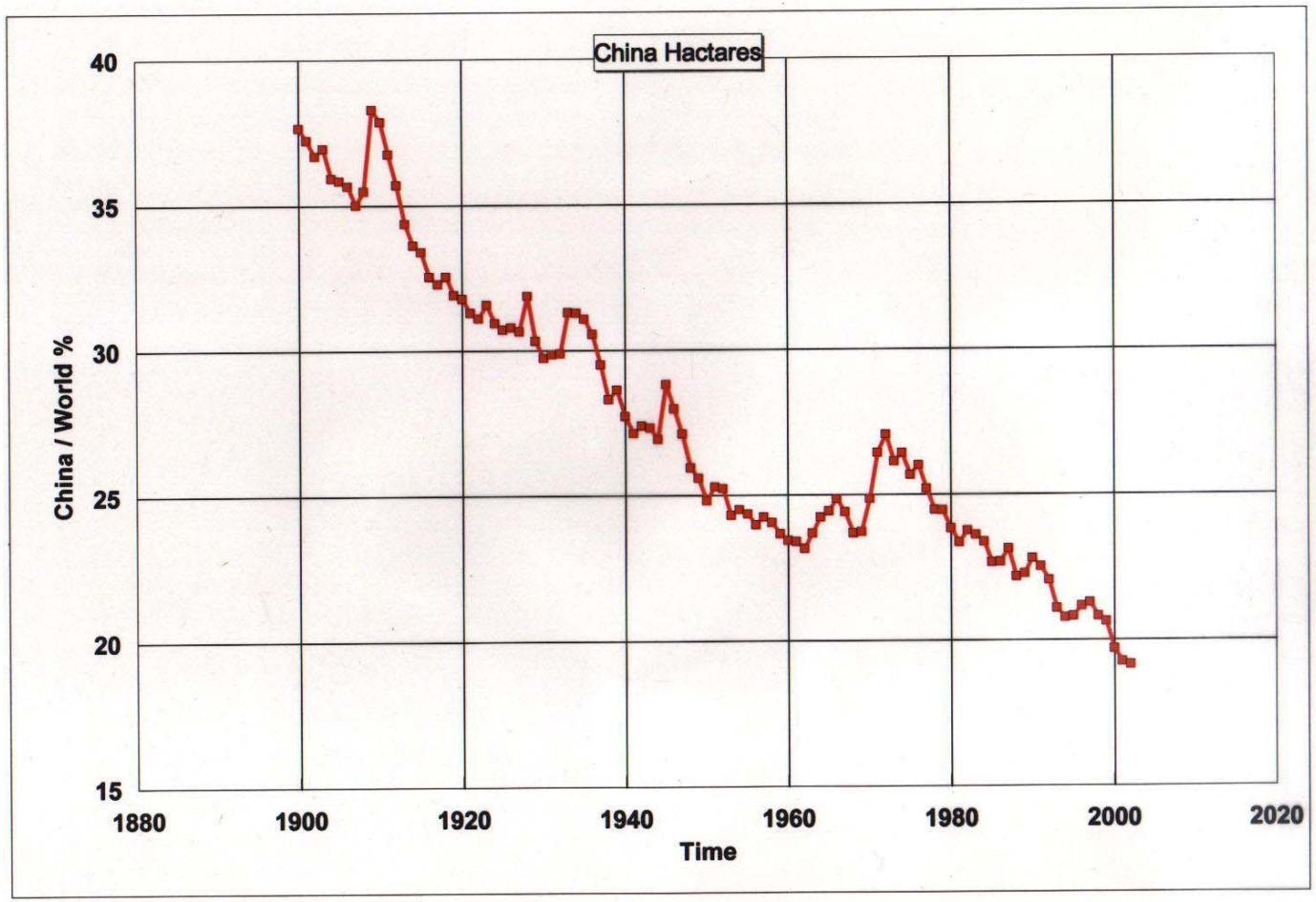

Methane Flux (Quin Yuan)
Methane Flux (mg/m^2/hr)
60
40
20
0
0
20
40
60
80
Days After Transplanting
Field 1
Field 2
Field 3

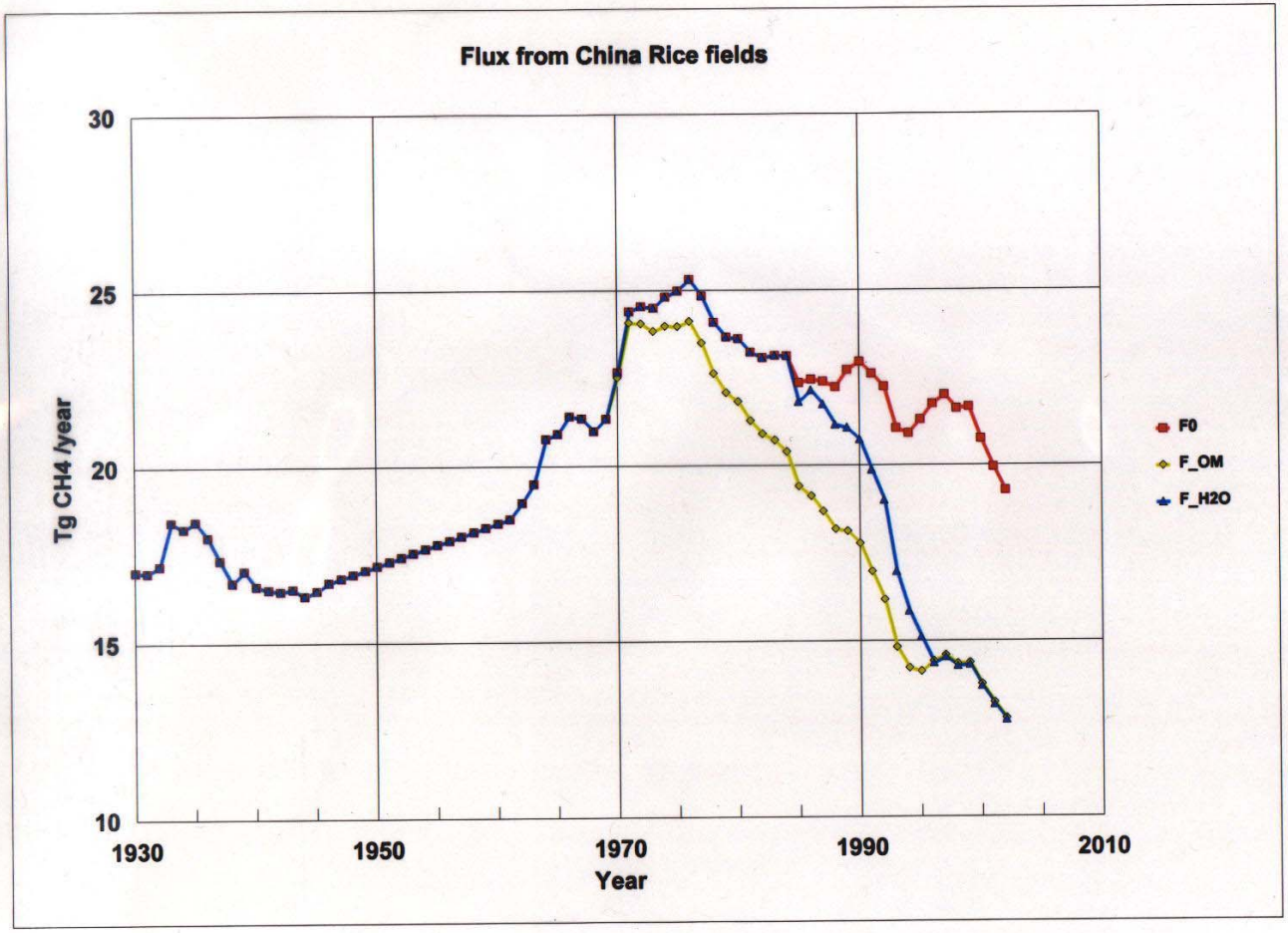

60
50
40
30
20
10
0
CH_4 Flux (mg/m^2/hr)
1988
1990
1992
1994
1996
1998
2000
Year
TuZu
JinSa
TuZu Average
JinSa Average


Fertilizer Use
CHINA N-Fertilizer (10^12 Tonnes)
WORLD
Time
0
10
20
30
0
20
40
60
80
100
1960
1970
1980
1990
2000
2010
china


Fertilizer Use
China / World %
40
30
20
10
0
1960
1970
1980
1990
2000
2010
Time

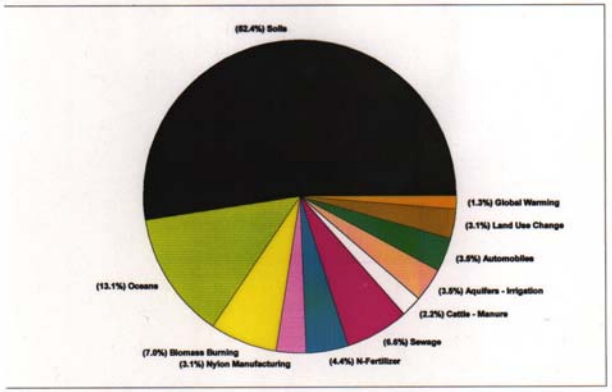

Hectares Harvested
CHINA Million Ha
WORLD
Time
38
36
34
32
30
28
26
160
150
140
130
120
110
1960
1970
1980
1990
2000
2010
China


China Hactares
China / World %
40
35
30
25
20
15
1880
1900
1920
1940
1960
1980
2000
2020
Time

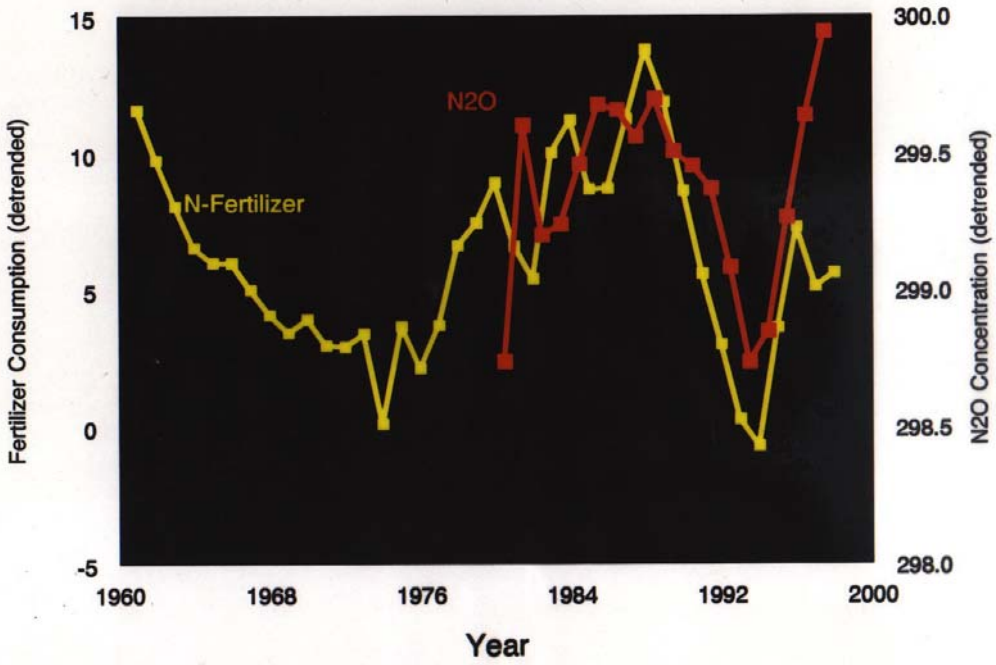

Flux from China Rice fields
30
25
20
15
10
Tg CH4 /year
1930
1950
1970
1990
2010
Year
F0
F_OM
F_H2O

N2O - Nitrous Oxide

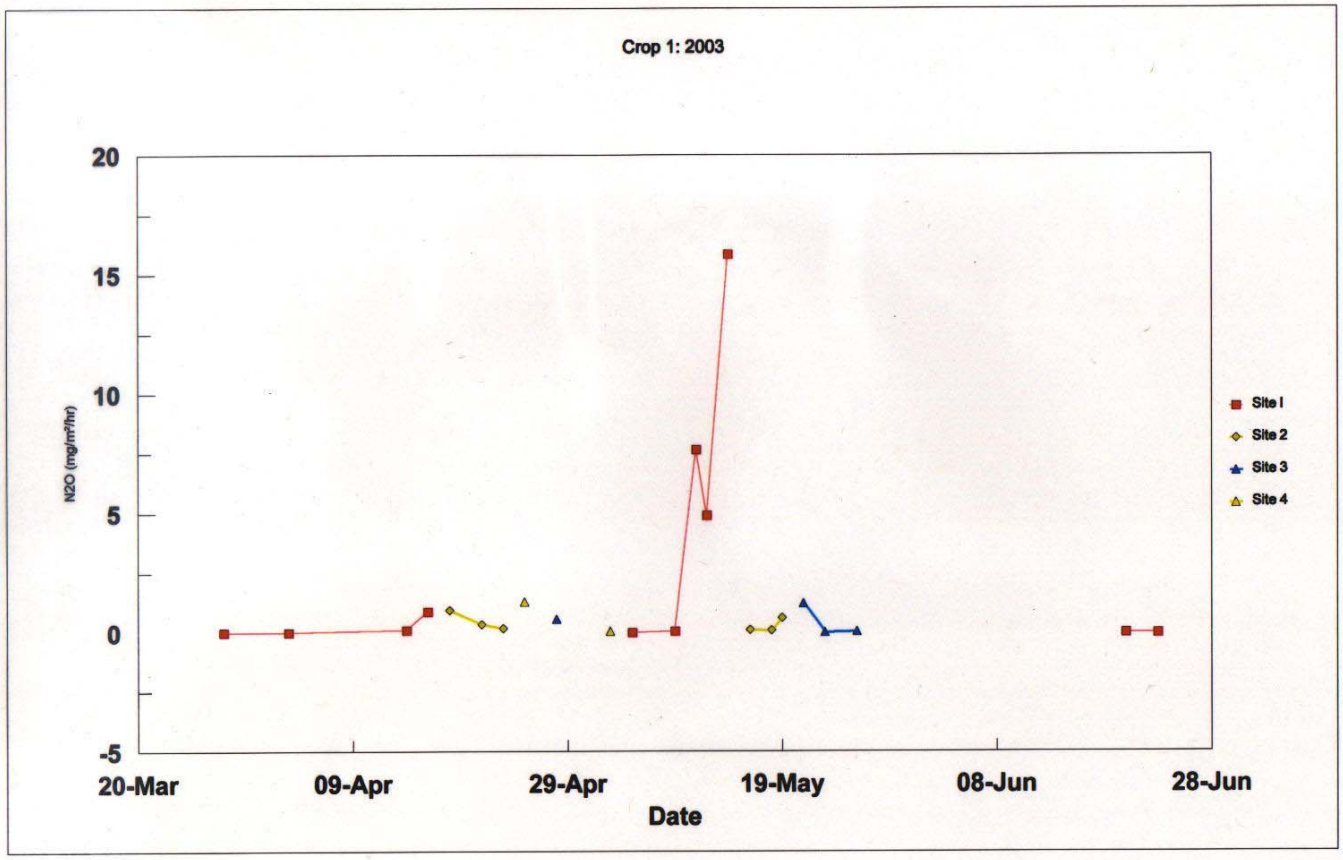
Source	Emissions (Tg/yr) Natural	Man-Made (Very Uncertain)
Soils	12	
Oceans	3	
Biomass Burning		1.6
Nylon Manufacturing		0.7
N-Fertilizer		1.0
Sewage		1.5
Cattle - Manure		0.5
Aquifers - Irrigation		0.8
Automobiles		0.8
Land Use Change		0.7
Atmospheric Formation		?
Global Warming		0.3
TOTALS	15	8
GRAND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



Nitrogen Fertilizer Use and N2O Concentrations
(DETRENDED)



Khalil and Rasmussen, 2001, Unpublished


Crop 1: 2003
20
15
10
5
0
-5
N2O (mg/m²/hr)
20-Mar
09-Apr
29-Apr
19-May
08-Jun
28-Jun
Date
Site 1
Site 2
Site 3
Site 4

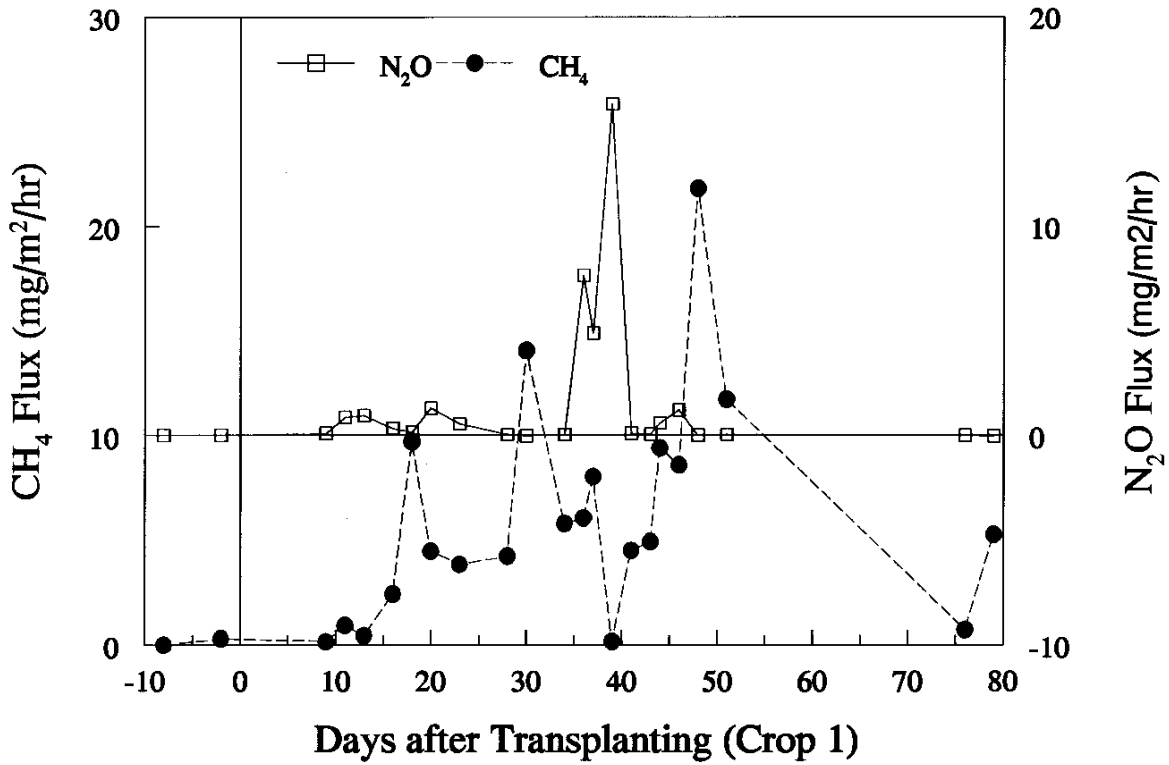


Figure 8. Methane flux vs. Nitrous oxide flux from rice fields near Qing Yuan, Guangzhou Province.

CONCLUSIONS

1. Methane emissions from rice fields in China have dropped during the last decade

   $\Delta F \sim 50\%$ OR 13-15 Tg/y

2. This change contributes significantly to the NET ZERO CH_4 global atmospheric trend at present

3. Role of Rice agriculture on greenhouse gases is shifting from CH_4 to N_2O