CH_4 and N_2O from rice paddies in 2006 IPCC GLs

&

Estimate of Japanese country specific N_2O emission factors

Hiroko Akiyama[†], Kazuyuki Yagi[†],

Xiaoyuan Yan*

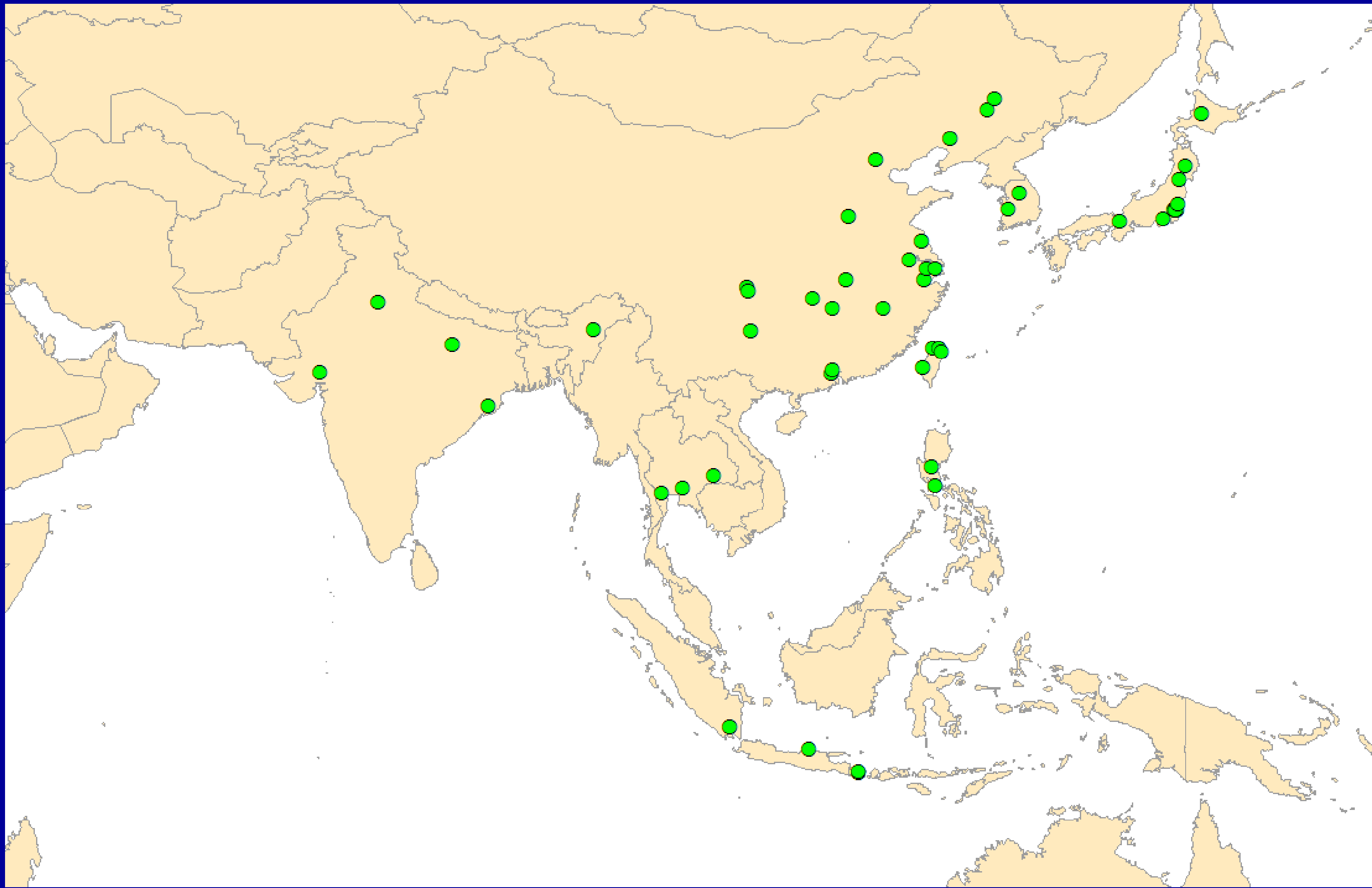
[†]National Institute for Agro-Environmental Sciences, Japan

*Frontier Research Center for Global Change

Current address: Nanjing Institute for Soil Science, China

1. CH_4 from rice paddies in 2006 IPCC GLs

A database of methane emission from rice field

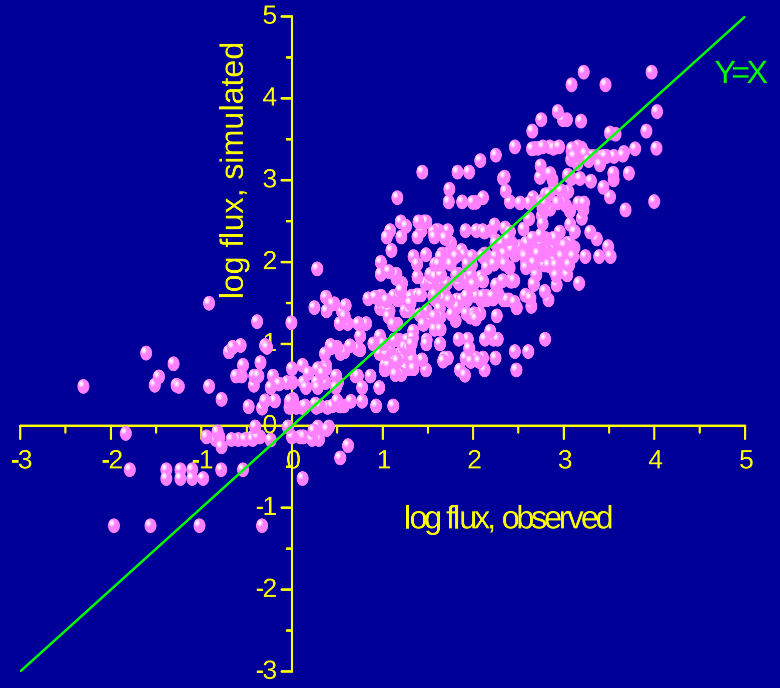


Collected over 800 field measurement data

A statistical model

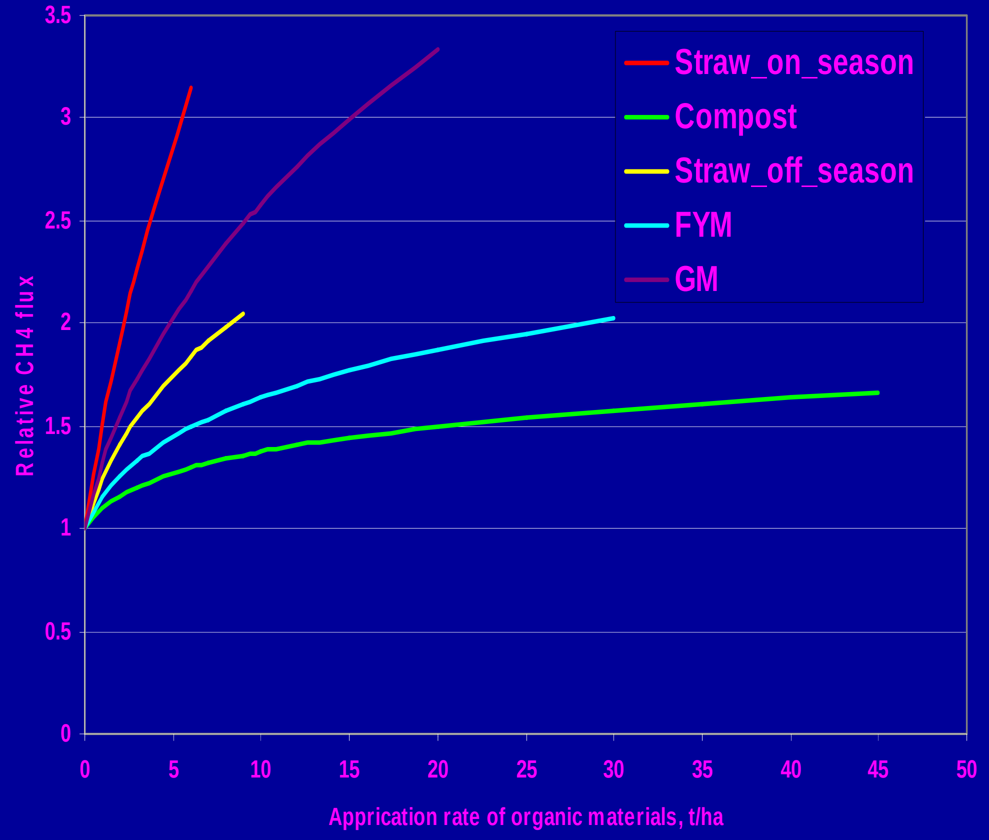
$$Ln(flux) = Intercept + a \times \ln(OC) + pH_m + PW_i + Water_j + Climate_k + OM_l \times \ln(1 + AOM)$$

- Soil properties: soil pH, SOC
- Preseason water: flooded, short drainage, long drainage
- Rice season water: continuous flooding, single drainage, multiple drainage
- Organic amendment: rice straw, rice straw off season, green manure, farm yard manure, compost
- Climate



Statistical results:
Effects of major influencing factors

Organic amendment



5.4 CH4 EMISSIONS FROM RICE CULTIVATION

EQUATION 5.4.1

CH_4 EMISSIONS FROM RICE CULTIVATION

$$\text{Emissions from Rice Cultivation (Gg/yr)} = \sum_i \sum_j \sum_k (EF_{ijk} \bullet t_{ijk} \bullet A_{ijk} \bullet 10^{-6})$$

i, j, and k: different ecosystems, water regimes, organic amendments, etc.

EQUATION 5.4.2

ADJUSTED SEASONALLY INTEGRATED EMISSION FACTOR

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

Default baseline emission

TABLE 5.11

DEFAULT CH_4 BASELINE EMISSION FACTOR ASSUMING NO FLOODING FOR LESS THAN 180 DAYS PRIOR TO RICE CULTIVATION, AND CONTINUOUSLY FLOODED DURING RICE CULTIVATION WITHOUT ORGANIC AMENDMENTS

	Emission factor	Error range
CH_4 emission (kg CH_4 ha^{-1} d^{-1})	1.30	0.80 - 2.20

Source: Yan et al., 2005

kg CH4 ha^{-1} day^{-1}

5.4 CH4 EMISSIONS FROM RICE CULTIVATION

Scaling factors for water regime

TABLE 5.4.2
DEFAULT CH_4 EMISSION SCALING FACTORS FOR WATER REGIMES DURING THE CULTIVATION PERIOD RELATIVE TO CONTINUOUSLY FLOODED FIELDS (WITHOUT ORGANIC AMENDMENTS)

Water Regime		Aggregated case		Disaggregated case	
		Scaling Factor (SF_w)	Error Range	Scaling Factor (SF_w)	Error Range
Upland[a]		0	-	0	-
Irrigated[b]	Continuously flooded	0.78	0.62-0.98	1	0.79-1.26
	Intermittently flooded – single aeration			0.60	0.46-0.80
	Intermittently flooded – multiple aeration			0.52	0.41-0.66
Rainfed[c]	Regular rainfed	0.27	0.21-0.34	0.28	0.21-0.37
	Drought prone			0.25	0.18-0.36
	Deep water			0.31	ND

Scaling factors for preseason water regime

TABLE 5.13
DEFAULT CH_4 EMISSION SCALING FACTORS FOR WATER REGIMES BEFORE THE CULTIVATION PERIOD

Water regime prior to rice cultivation (schematic presentation showing flooded periods as shaded)		Aggregated case		Disaggregated case	
		Scaling factor (SF_p)	Error range	Scaling factor (SF_p)	Error range
Non flooded pre-season <180 d	< 180 d CROP	1.22	1.07 - 1.40	1	0.88 - 1.14
Non flooded pre-season >180 d	> 180 d CROP			0.68	0.58 - 0.80
Flooded pre-season (>30 d)[a,b]	> 30 d CROP			1.90	1.65 - 2.18

[a] Short pre-season flooding periods of less than 30 d are not considered in selection of SFp

[b] For calculation of pre-season emission see below (section on completeness)

Source: Yan *et al.*, 2005

2006 IPCC Guidelines for National Greenhouse Gas Inventories

5.4 CH4 EMISSIONS FROM RICE CULTIVATION

Scaling factor for organic amendments

EQUATION 5.3
ADJUSTED CH_4 EMISSION SCALING FACTORS FOR ORGANIC AMENDMENTS

$$SF_o = \left(1 + \sum_i ROA_i \bullet CFOA_i\right)^{0.59}$$

TABLE 5.14
DEFAULT CONVERSION FACTOR FOR DIFFERENT TYPES OF ORGANIC AMENDMENT

Organic amendment	Conversion factor (CFOA)	Error range
Straw incorporated shortly (<30 days) before cultivation[a]	1	0.97 - 1.04
Straw incorporated long (>30 days) before cultivation[a]	0.29	0.20 - 0.40
Compost	0.05	0.01 - 0.08
Farm yard manure	0.14	0.07 - 0.20
Green manure	0.50	0.30 - 0.60

[a] Straw application means that straw is incorporated into the soil, it does not include case that straw just placed on the soil surface, nor that straw was burnt on the field.

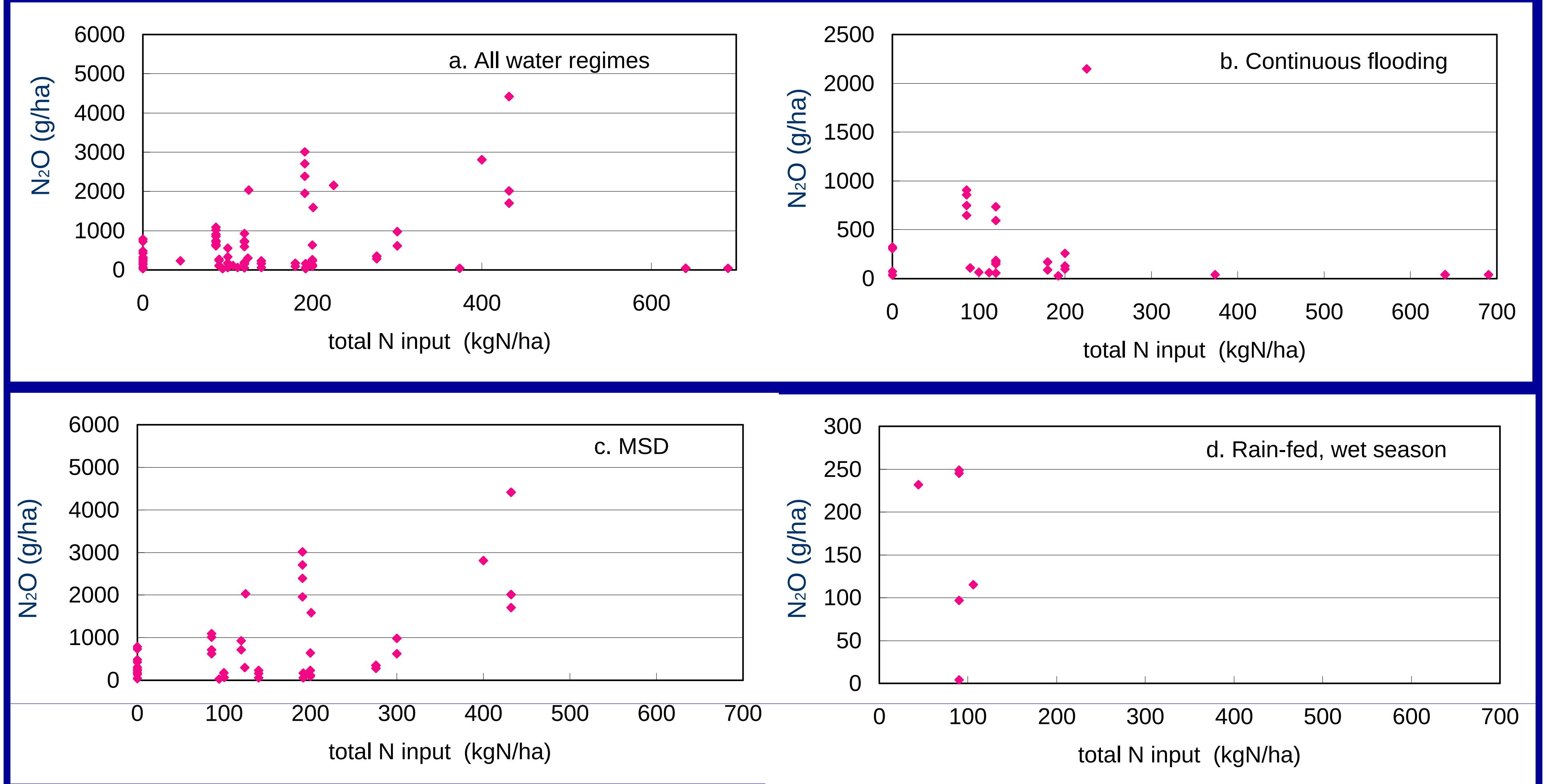
Source: Yan *et al.*, 2005

2. N_2O from rice paddy fields in 2006 IPCC GLs

Materials & Methods:

- Collected results of N_2O emission from rice fields published in peer-reviewed journals before 2004
- After excluding some extreme data (e.g., atypical field management), 113 measurements from 17 sites were used.
    - China (8 sites), India (1 site), Indonesia (1 site), Japan (4 sites), Philippines (2 sites), USA (1 site)

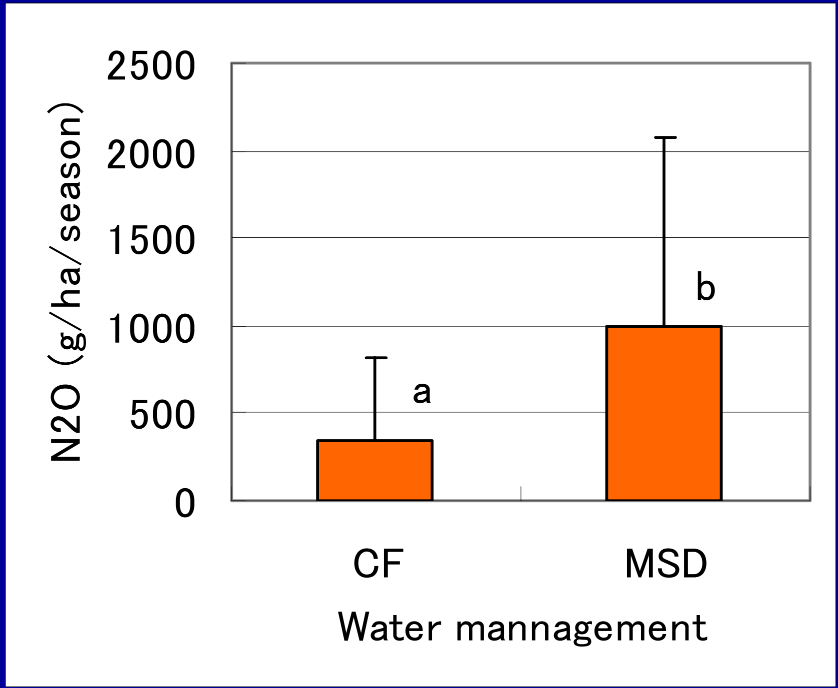
- *Classification of water regime*
  - Continuous flooding (CF)
    - Fields flooded whole rice growing season and drained only at the end of the season.
  - Midseason drainage (MSD)
    - Fields drained one or more times during the rice-cropping season. (Common practice in Japan)
  - Rain-fed, wet season (RF)
    - Fields with no irrigation system and planted during wet season.



Relationships between total N input and N_2O emission during the growing season.

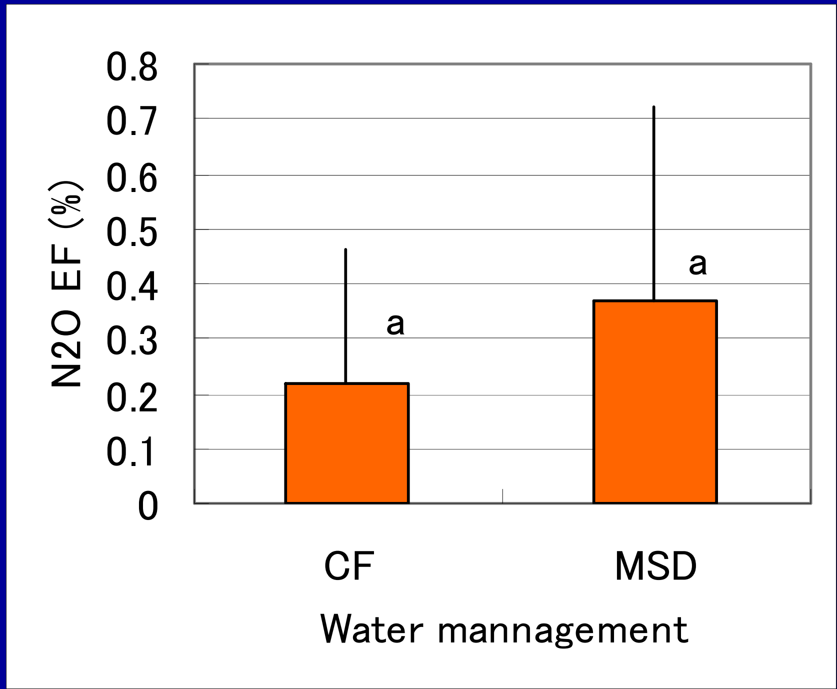
- N_2O emission : CF < MSD
- All water regime & CF : No clear relationship
- MSD : a weak linear relationship (r^2 = 0.28, P < 0.01)

Mean N_2O emission from fertilized fields during cropping season



N_2O emission：MSD ＞ CF

Mean EF during cropping season



- No significant difference between CF and MSD
- Mean EF = 0.31 %

The IPCC default emission factors for N_2O from agricultural soil (IPCC, 2006)

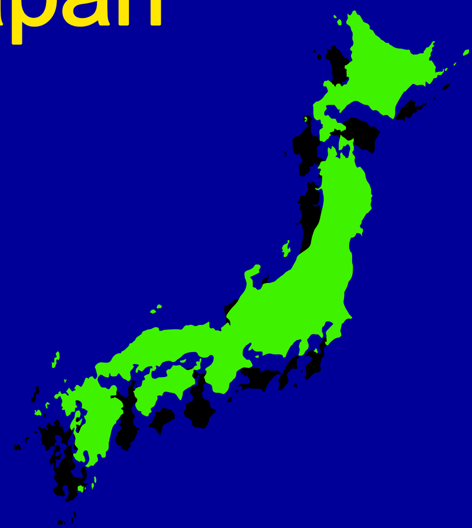
TABLE 11.1
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS

Emission Factor	Default Value	Uncertainty Range
EF_1 for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O-N (kg N)$^{-1}$]	0.01	0.003-0.03
EF_{1FR} for flooded rice fields [kg N_2O-N (kg N)$^{-1}$]	0.003	0.000-0.006
$EF_{2CG,Temp}$ for temperate organic crop and grassland soils (kg N_2O-N ha^{-1})	8	2-24
$EF_{2CG,Trop}$ for tropical organic crop and grassland soils (kg N_2O-N ha^{-1})	16	5- 48
$EF_{2F,Temp,Org,R}$ for temperate and boreal organic nutrient rich forest soils (kg N_2O-N ha^{-1})	0.6	0.16-2.4
$EF_{2F,Temp,Org,P}$ for temperate and boreal organic nutrient poor forest soils (kg N_2O-N ha^{-1})	0.1	0.02-0.3
$EF_{2F,Trop}$ for tropical organic forest soils (kg N_2O-N ha^{-1})	8	0-24
$EF_{3PRP,CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O-N (kg N)$^{-1}$]	0.02	0.007-0.06
$EF_{3PRP,SO}$ for sheep and 'other animals' [kg N_2O-N (kg N)$^{-1}$]	0.01	0.003-0.03

Sources:

EF_1: Bouwman et al. 2002a,b; Stehfest & Bouwman, in press; Novoa & Tejeda in press; EF_{1FR}: Akiyama et al., 2005; $EF_{2CG,Temp}$, $EF_{2CG,Trop}$, $EF_{2F,Trop}$: Klemedtsson et al., 1999, IPCC Good Practice Guidance, 2000; $EF_{2F,Temp}$: Alm et al., 1999; Laine et al., 1996; Martikainen et al., 1995; Minkkinen et al., 2002: Regina et al., 1996; Klemedtsson et al., 2002; $EF_{3,CPP}$, $EF_{3,SO}$: de Klein, 2004.

3. Estimate of country specific N_2O emission factors from agricultural soils in Japan



Before revision: The National Greenhouse Gas Inventory Report of Japan (2005)

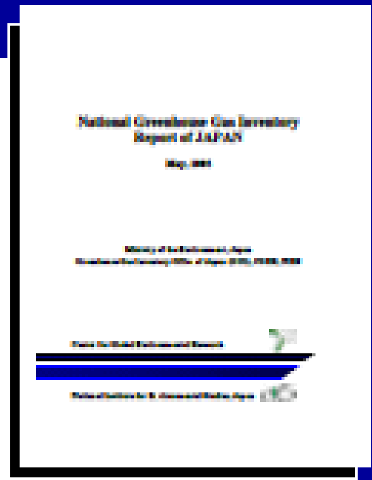


Table 6-19 Nitrous oxide emission factors, by type of crop

Type of crop	Emission Factors [kgN_2O-N/kgN]
Vegetables	0.00773
Rice	0.00673
Fruit	0.0069
Tea	0.0474
Potatoes	0.0201
Pulse	0.0073
Feed crops	0.006
Sweet potato	0.00727
Wheat	0.00486
Buckwheat	0.0073
Mulberries	0.0073
Industrial crops	0.0073
Tobacco	0.0073

Source: Haruo Tsuruta, *Establishment of GHGs reduction model*, Incorporated foundation, Society for the Study of Agricultural Technology, *A Report on an Investigation of how to quantify the amount of Greenhouse Gases Emissions reduced in 2000F.Y.*

- Tier 2: country specific EFs : 13 different EFs by crop type based on a report by Tsuruta (2001)

Advantages and disadvantages of the EFs in the *National GHGs Inventory Report of Japan* (2005)

- Advantage:
  - based on the most extensive measurement campaign of N_2O emissions from Japanese agricultural fields conducted from 1992 to 1994.
- Disadvantages:

  (1) background emission is included in EFs,
  because of lack of data at that point.

  (2) Measurement periods were not sufficient to estimate annual emissions — 3 months in many cases, but less than 2 months in some cases.

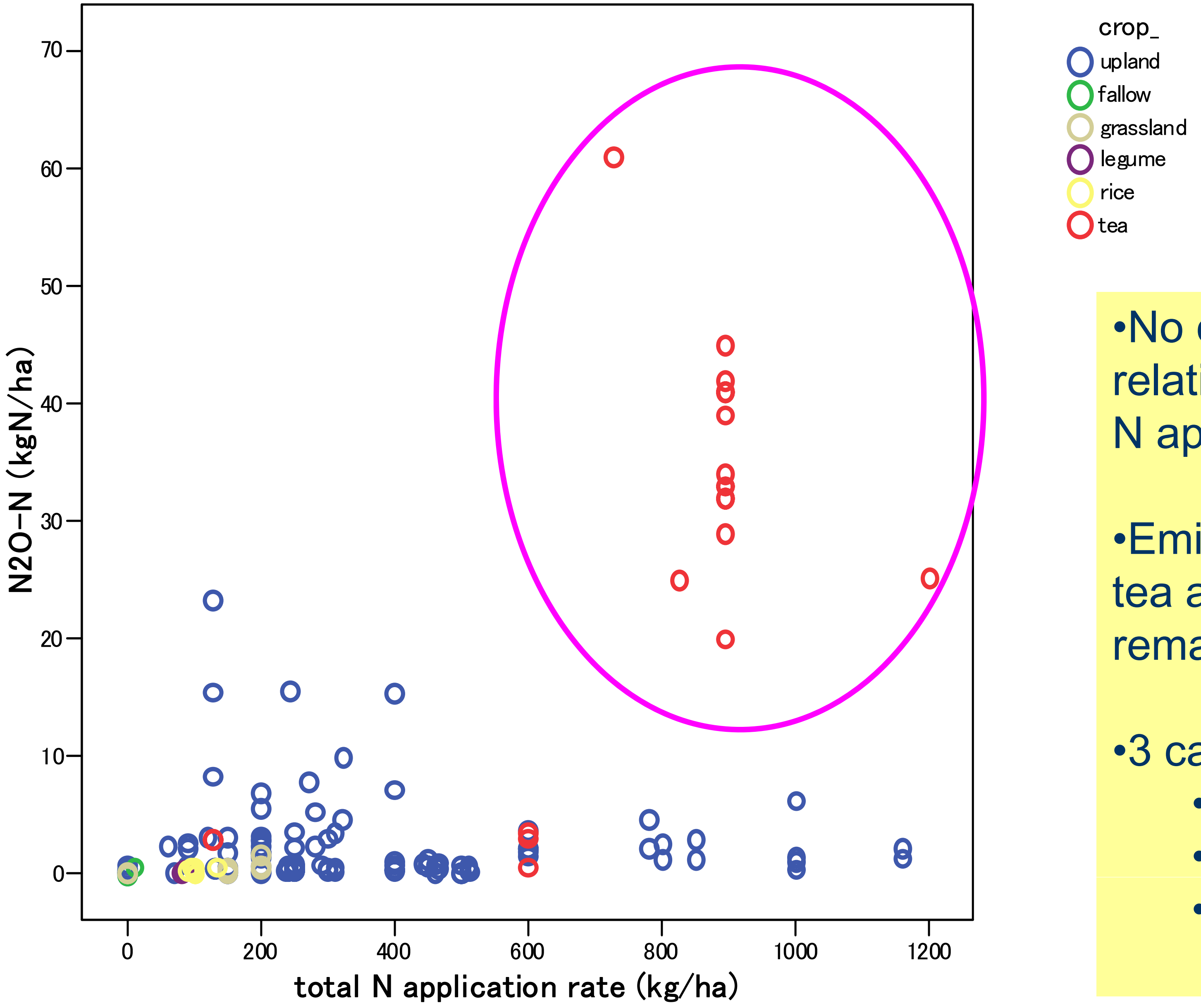
And also…

Small number of data were

Need for Revision

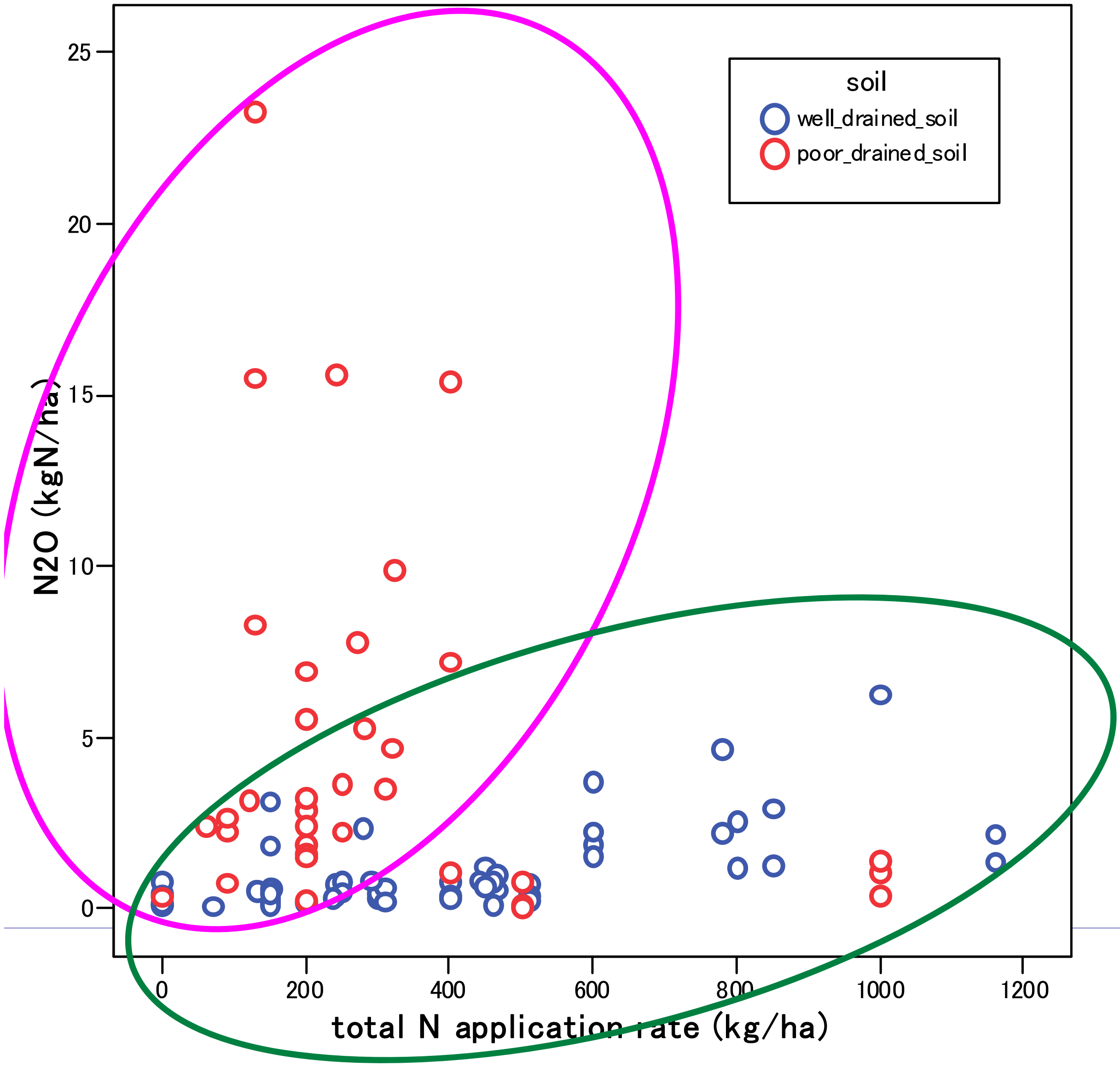
Collected data

- N_2O emissions from Japanese agricultural fields
  - 246 measurements from 36 sites
  - reported in peer-reviewed journals and research reports, published before 2005.



- No clear relationship with N application rate
- Emissions from tea are remarkably high
- 3 categories:
  - tea
  - paddy rice
  - upland

Relationship between N inputs and N_2O emissions from different crop types



upland

- Soil drainage classes were categorized from soil types
- Poorly drained soil > well-drained soil
- No clear relationship for poorly drained soil
- Well-drained soil: R^2= 0.38

Relationship between N inputs and N_2O emissions from upland fields with different soil drainage type (measurement period more than 90 days)

Table
Summary of N_2O-N emission and
fertilizer induced N_2O-N emission factor from Japanese upland field (except tea filed)
measurement period more than 90 days

soil drainage #	n	mean		standard deviation		median	min	max
N_2O-N emission (kgN ha-1)								
well drained soil	67	1.03	a**	1.14		0.61	0.09	6.28
poorly drained soil	35	4.78	b	5.36		2.88	0.07	23.3
Fertilizer induced N_2O-N emission factor (%)								
well drained soil	15	0.32	a**	0.49		0.16	0.07	2.02
poorly drained soil	9	1.40	b	0.95		1.26	0.57	3.30
estimated emission factor for all soil		0.62	$	0.48	$$			

☻ poorly drained soil ＞ well-drained soil

☻ EF for upland = 0.62 ± 0.48 % (weighted by area of soil type)

☻ measurement period: more than 90 days

assuming that most of the fertilizer-induced N2O emission should be included in this period, because data availability

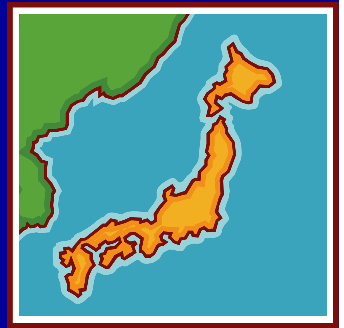
Table
Summary of N2O-N emission (kg ha-1) and
Fertilizer induced N2O-N emission factor (%) from Japanese tea fields

	n	mean	standard deviation	median	min	max
N2O-N emission (kgN ha-1)						
	26	24.3	16.3	27.11	2.39	61.0
Estimated fertilizer induced emission factor (%) $						
	26	2.82	1.80	3.02	0.35	8.25

☻ background emission was assumed as same as IPCC default value (1kg ha-1),
because no reliable data from zero-N control plot was available.

☻ Measurement period: 210 to 365 days

Summary of estimated EF for Japanese Agricultural soil



- Upland = 0.62 ± 0.48 %
  - lower than the IPCC default EF of 1%.
  - lower than the EF of 0.8% by FAO/IFA (2001).
    - poorly drained soils are mainly used for rice paddy fields in Japan.
    - Ratio of well-drained soil among upland field is relatively high (78%) in Japan.

- Tea = 2.82 ± 1.82 %
- Rice paddy = 0.31 ± 0.31 %
  - *estimated from N2O emission data of rice paddy fields worldwide (Akiyama et al., 2005; IPCC, 2006)

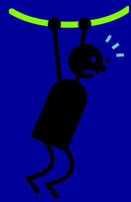
4. Issues related to compiling GHG database for inventory work

~ estimate EF from papers with field measurement data

Missing information

- Lack of basic information in many papers
  - soil type, soil property, type and amount of chemical and organic fertilizer, etc
  - impossible to calculate total emission
    - Only average flux is shown, but measurement period is not stated.
    - Only emission from fertilizer applied area of band application is shown, but not emission from entire field.

How to get representative data



- Each paper have its own objective, not for GHG inventory
  - Few measurement include zero N control, which is needed to calculate fertilizer induced emission factor
  - Measurement periods of many experiment are not enough to estimate annual emission
- Danger of Bias : location, crop, soil type, etc
  - Each field measurement are planned individually, Not systematically designed for inventory
  - Small number of data is easily to be biased – get enough number of data to represent your country, otherwise default EF is better than country specific EF!

Thank you!