Bottom-up anthropogenic methane emission inventories in China from 1980 to 2010

Shushi Peng, Shilong Piao, Yuan Zhang, Binghui Chen, Liqing Peng, Bengang Li, Shu Tao, Zehao Shen, Philippe Ciais

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Abstract: Using IPCC Guidelines (IPCC, 2006) Tier 1/2 methods, anthropogenic methane emissions over China from 1980 to 2010 were estimated by bottom-up inventories. The total anthropogenic methane emissions were estimated from 9 sectors: livestock (including enteric fermentation and manure management), rice, biomass burning (including inside and outside), fugitive from coal mining and oil, gas production and transmission, fuel combustion, landfills, domestic swedge and industrial waste water. During the past three decades, the total anthropogenic CH_4 emissions in China increase from 21.7±3.7 Tg CH_4 yr^{-1} in 1980 to 45.5±5.6 Tg CH_4 yr^{-1} by bottom-up inventory, which is about ~10% of global CH_4 net emission. The yearly anthropogenic CH_4 emission maps for each sector from 1980 to 2010 at spatial resolution of half-degree were also produced by bottom-up inventories.

Anthropogenic methane emissions in China from 1980 to 2010

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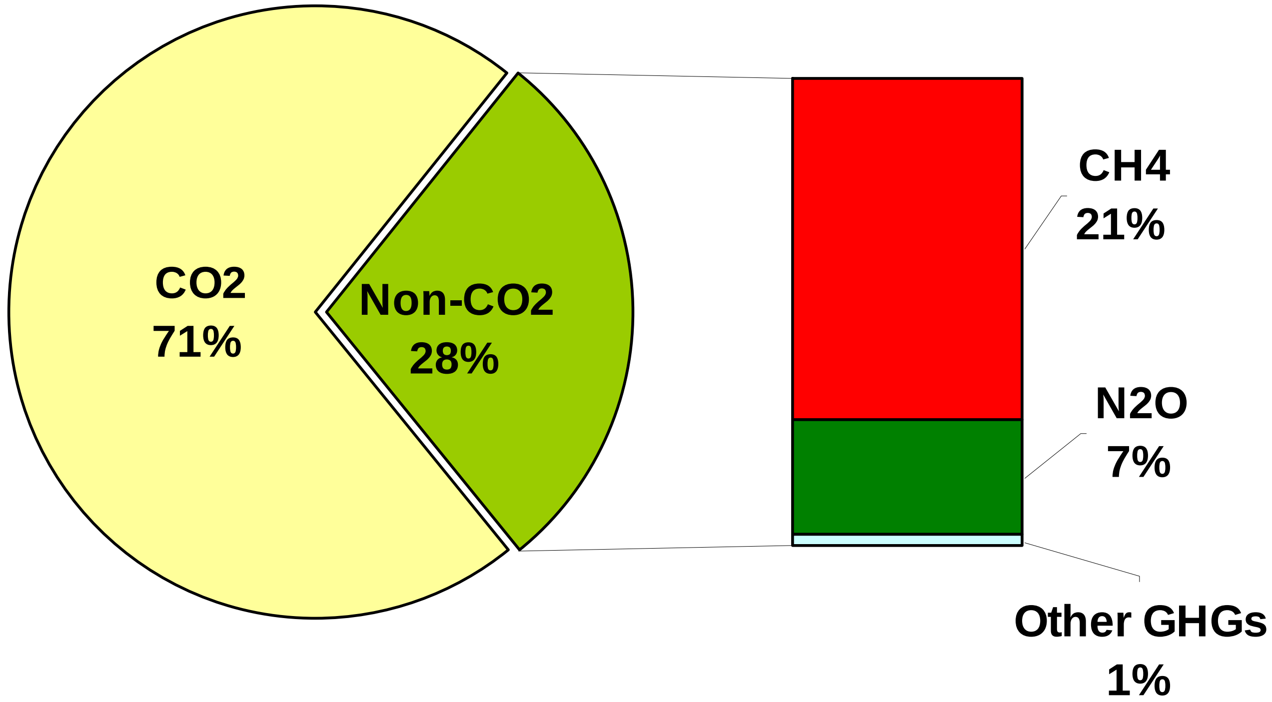
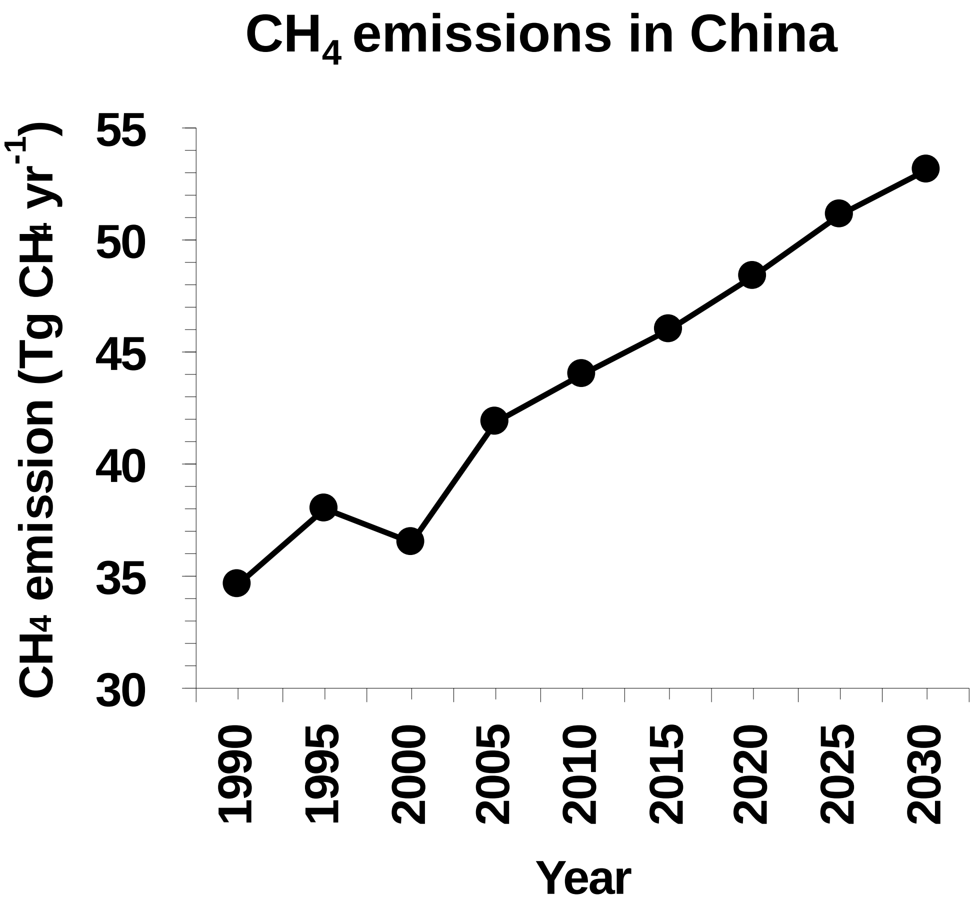
Motivation



Second anthropogenic greenhouse gas in terms of radiative forcing

Motivation

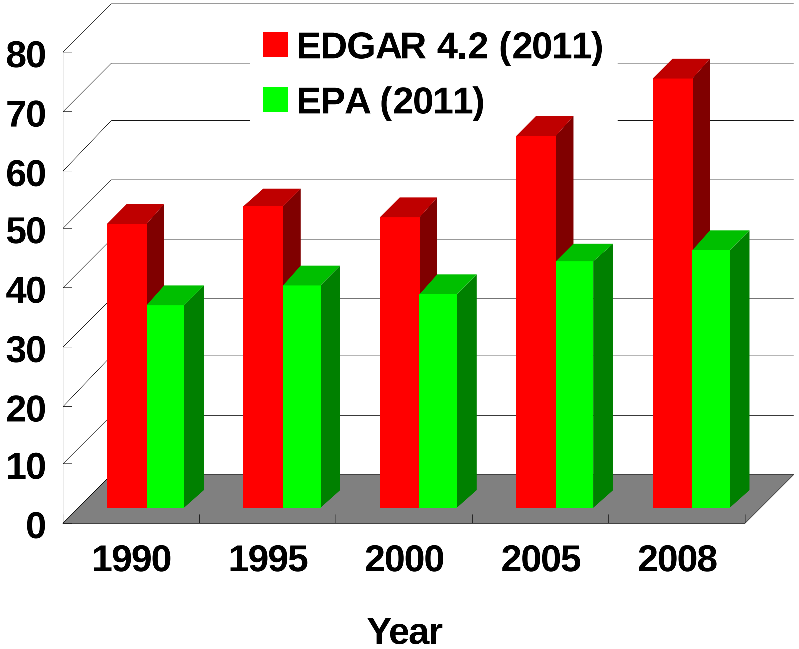


Since 2005, China is NO.1 in CH4 emission.

(www.globalmethane.org)

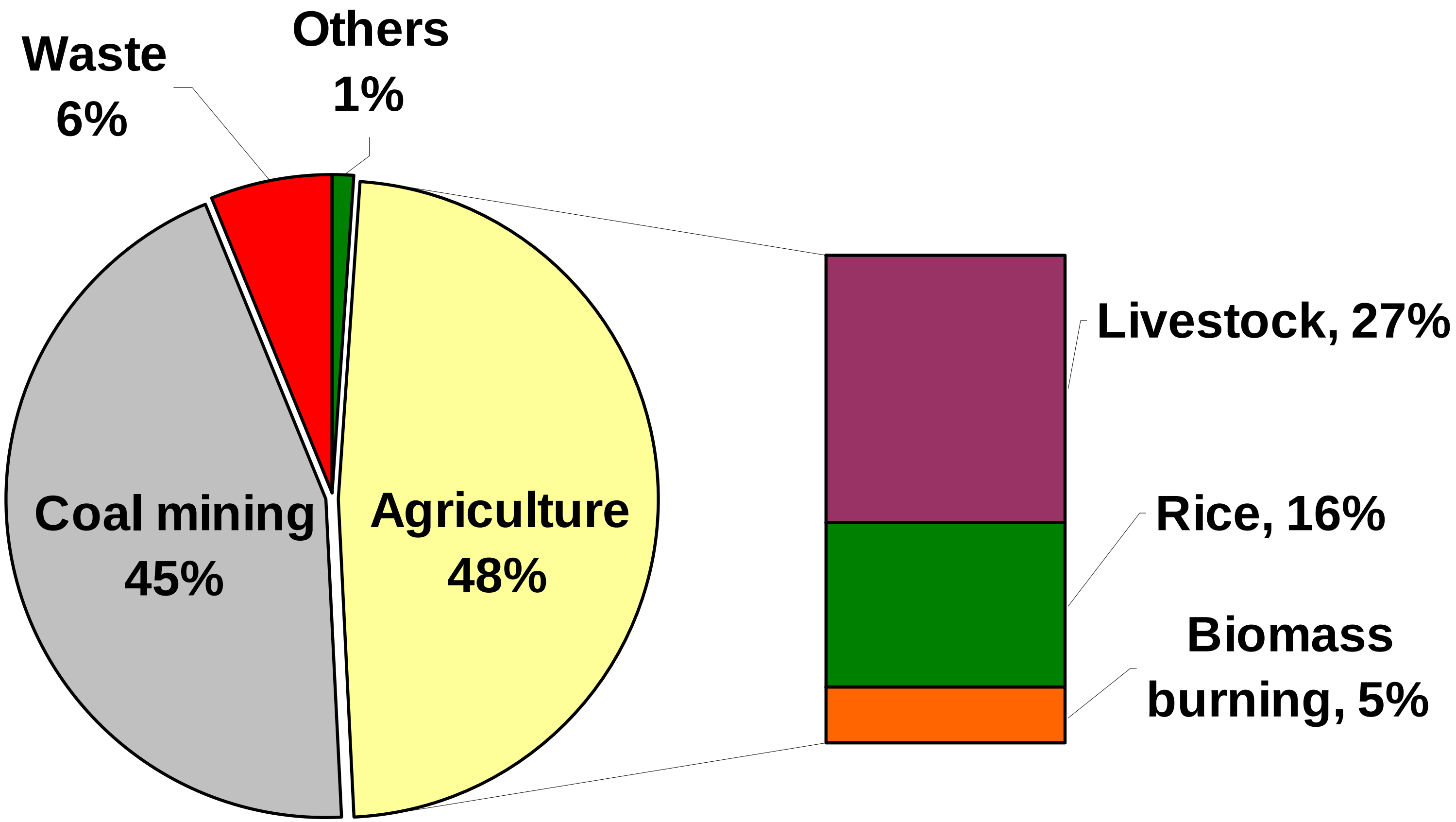
Motivation

Big uncertainty in CH_4 emissions in China



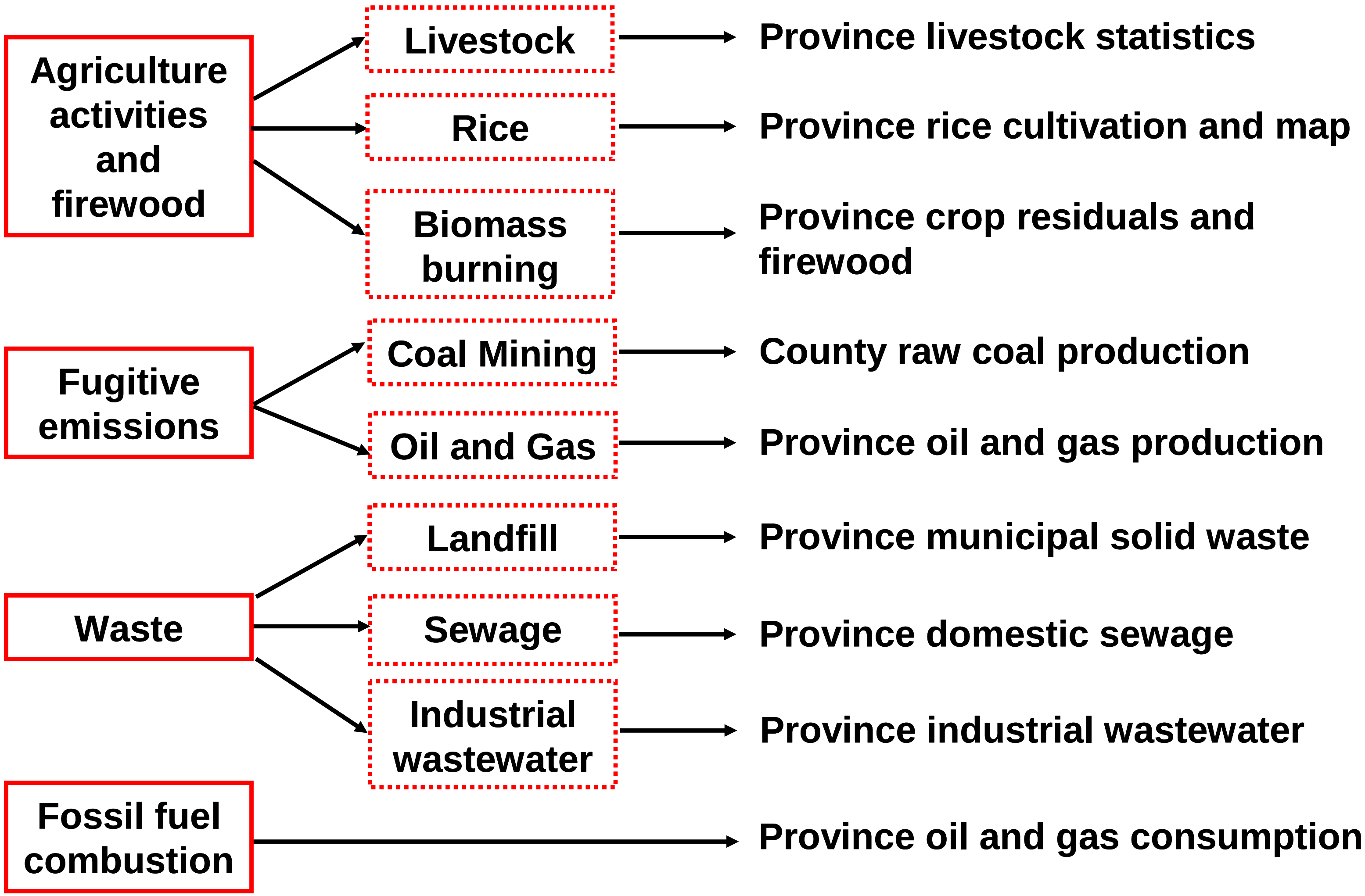
~30 Tg CH4 yr^{-1} difference between EDGAR 4.2 (2011) and EPA (2011) in 2008, and Zhang et al. (2010) reported China emit ~40 Tg CH4 in 2007.

Sources of CH_4 emissions in China



EPA, 2011; Zhang et al., 2010, Energy Policy

Methods and Datasets



Methods and Datasets

County level:

- Population
- Rural population
- GDP of agriculture
- GDP of industry,
- Total GDP

→ **Interpolation high spatial resolution CH_4 emissions maps**

Data sources:

- China Agriculture Yearbook
- China Energy Statistical Yearbook
- China Environment Yearbook
- China Statistical Yearbook

Fugitive CH_4 emissions from coal mining and oil and gas systems

CH_4 emissions from coal mining

EQUATION 4.1.3

TIER 1: GLOBAL AVERAGE METHOD – UNDERGROUND MINING – BEFORE ADJUSTMENT FOR ANY METHANE UTILISATION OR FLARING

$$Ch_4\ emissions = CH_4\ Emission\ Factor \bullet Underground\ Coal\ Production \bullet Conversion\ Factor$$

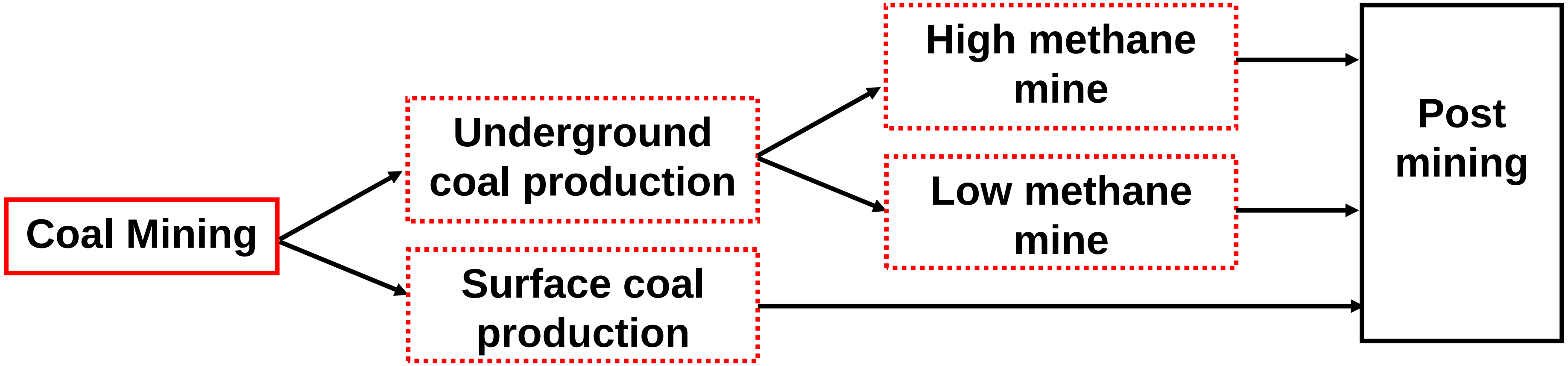
Where units are:

Methane Emissions (Gg $year^{-1}$)

CH_4 Emission Factor (m^3 $tonne^{-1}$)

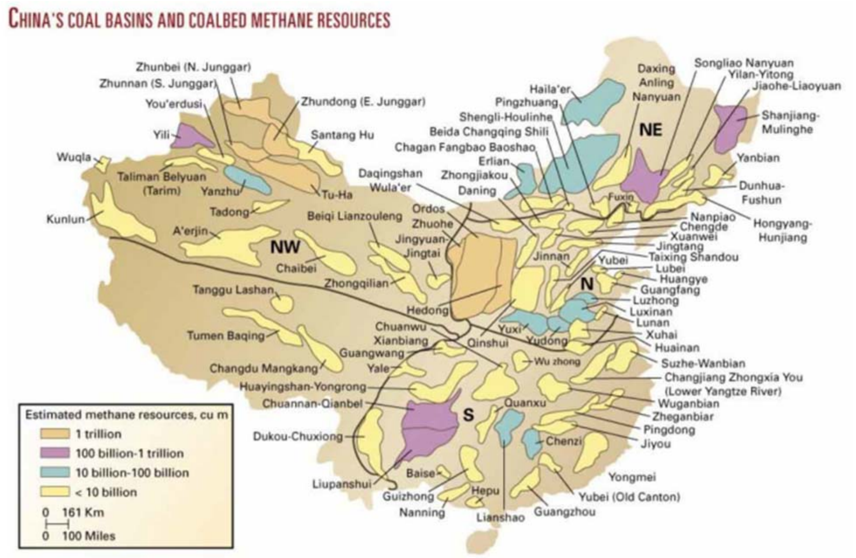
Underground Coal Production (tonne $year^{-1}$)

IPCC GHGs guideline, (2006)



CH_4 emission factors of coal mining

	Coal mining (m^3/t)		Post-mining (m^3/t)	
	Zhang and Chen, (2010)	IPCC, 2006	Zhang and Chen, (2010)	IPCC, 2006
High methane mine	**21.83**	**18**	**3.02**	**2.5**
Low methane mine	**4.53**	**18**	**1.13**	**2.5**
Surface	**2.5**	**1.2**	**0.1**	**0.1**

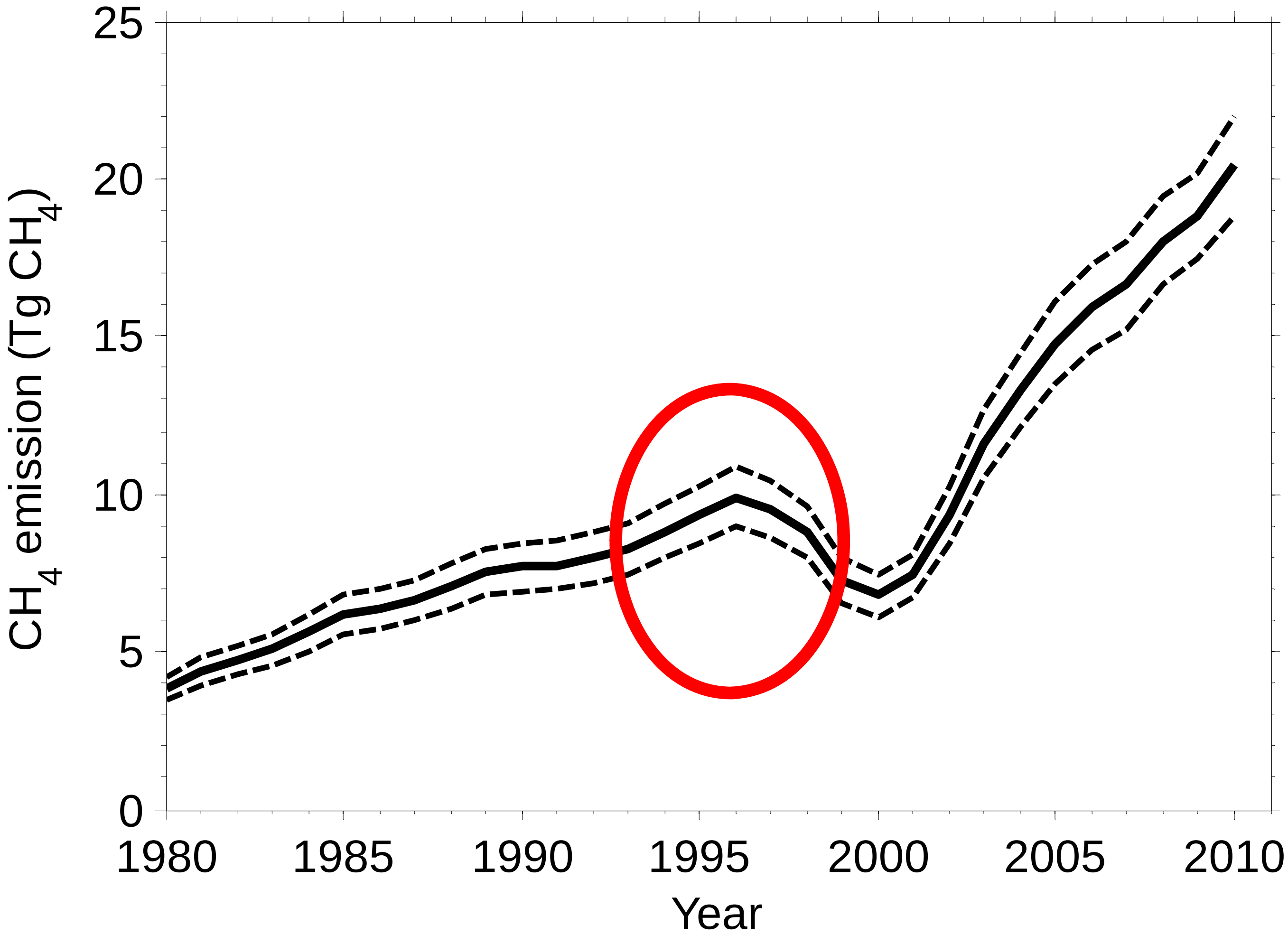


Source: Liu (2007)

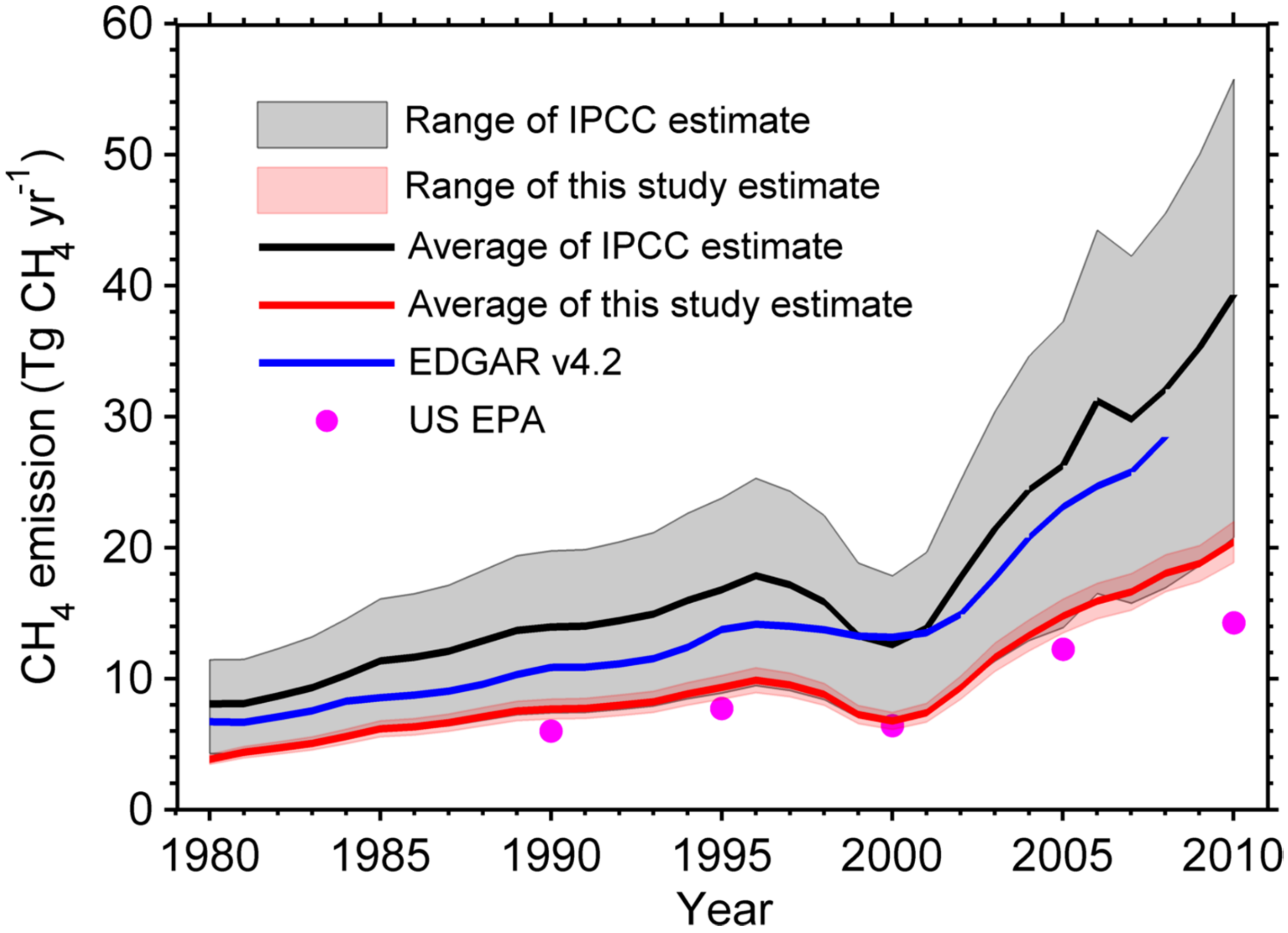
	CH_4 emission factors (m^3/t)	
	1994	2000
North	**4.18**	**6.97**
Northeast	**11.75**	**14.40**
Northwest	**6.00**	**5.97**
Southwest	**19.02**	**21.68**
Central and South	**7.19**	**7.83**
East	**5.46**	**6.22**
China	**7.92**	**9.30**

Zheng et al., (2006)

CH_4 emissions from coal mining

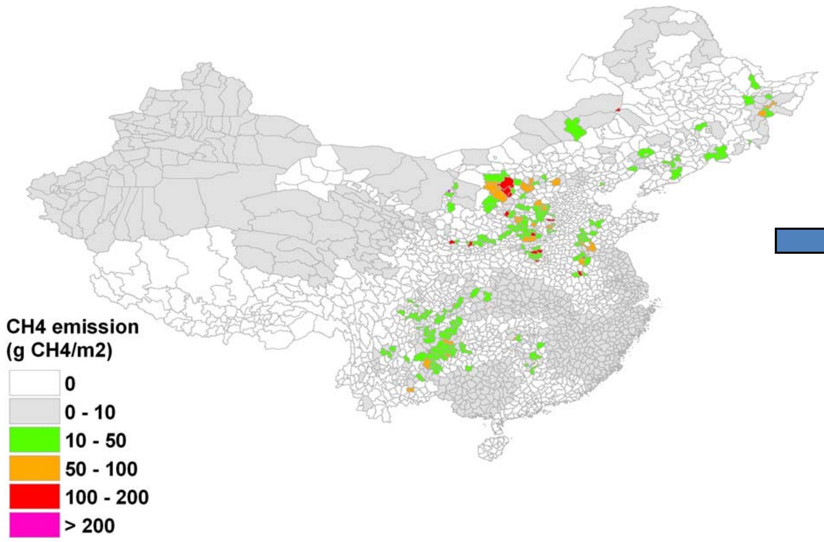


CH_4 emissions from coal mining

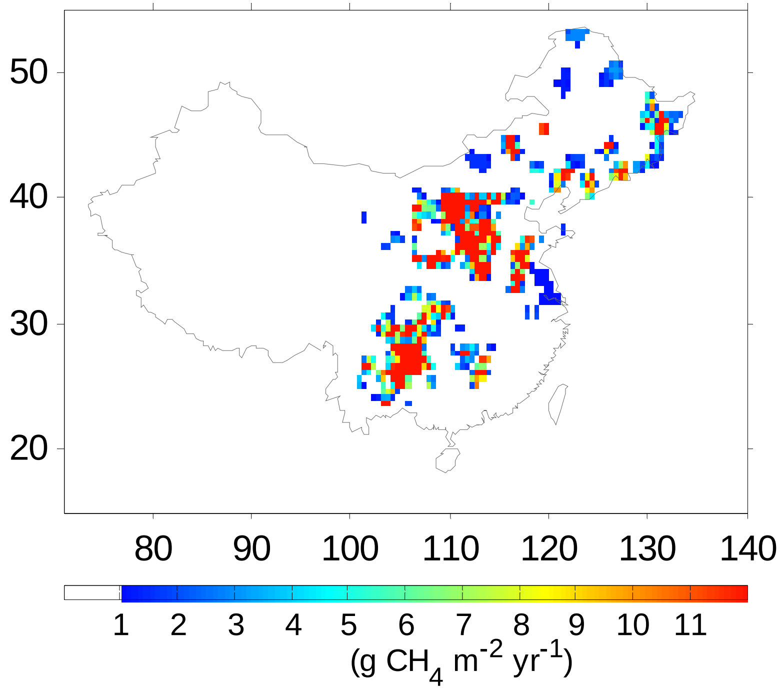


Spatial patterns of CH_4 emissions from coal mining

County level



0.5° ×0.5° grid

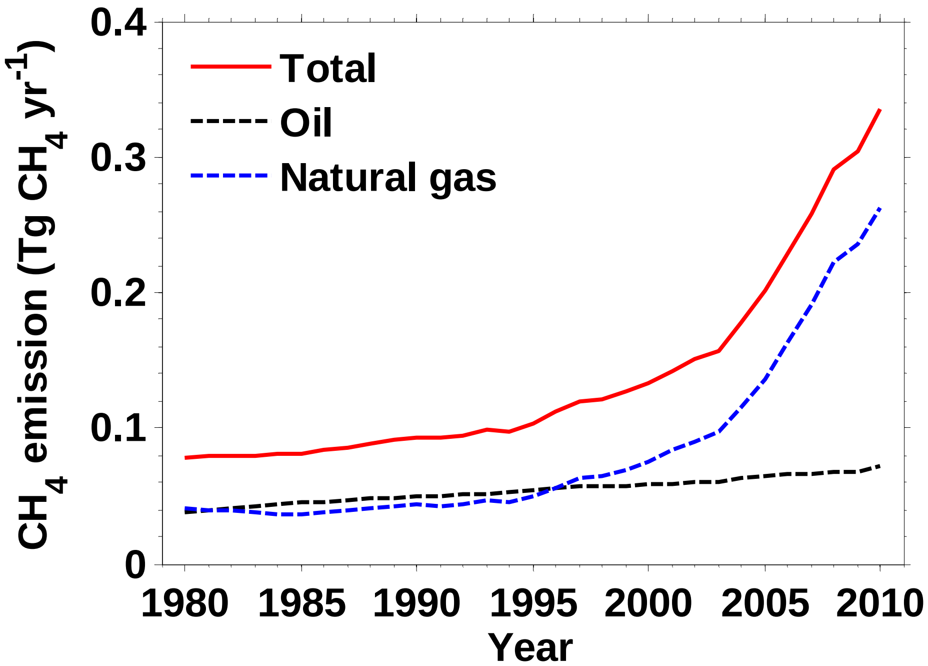


CH_4 emissions from oil and gas systems

Table 5
Fugitive emissions from oil and natural gas systems.

Fugitive emission	Petroleum	Natural gas	Total
Output	18,135.29 (10^4 t)	493.20 (10^8 m^3)	
Emission factors	3.57×10^{-7} (Gg/t)	2.77×10^{-9} (Gg/m^3)	
Emission (Gg)	66.52	191.79	258.31

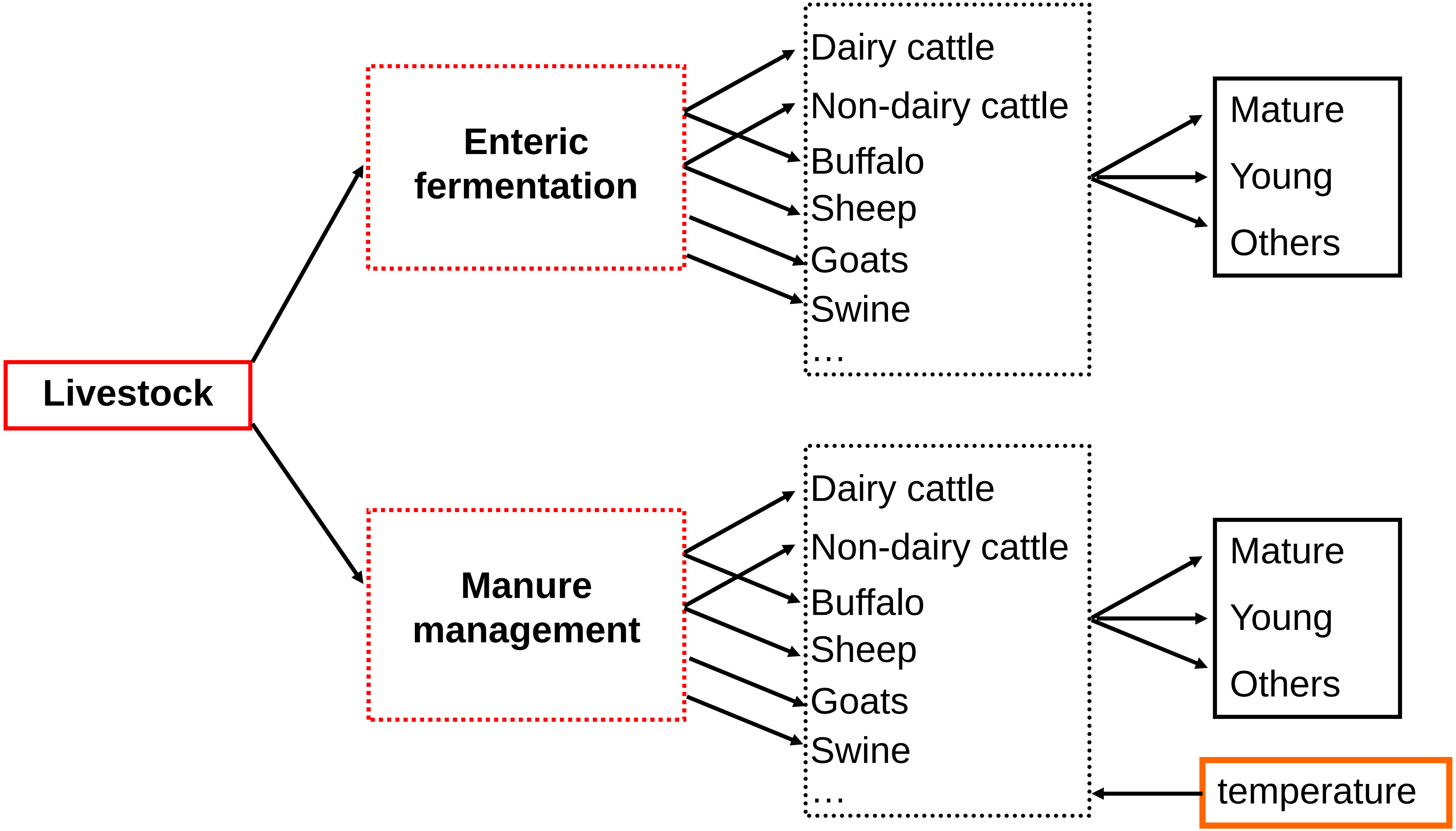
Zhang et al., (1999); Zhang & Chen, (2010);



CH_4 emissions from agricultural activities

- Livestock
- Rice cultivation
- Biomass burning

CH_4 emissions from livestock



CH_4 emissions factors of livestock

		Enteric fermentation (kg CH_4 head^{-1} year^{-1})	Manure management (kg CH_4 head^{-1} year^{-1})	*Total* (kg CH_4 head^{-1} year^{-1})
Non-dairy cattle	Mature female	59.69	44.00	64.00
	Young (<1 yr)	34.92	28.50	54.21
	Other	57.53	44.00	66.00
Dairy cattle	Mature female	78.49	44.00	78.49
	Young (<1 yr)	39.90	38.40	65.25
	Other	57.90	44.00	65.25
Buffalo	Mature female	87.55	48.00	87.55
	Young (<1 yr)	48.04	38.40	72.92
	Other	68.23	48.00	72.92
Others		57.53	44.00	66.00
Sheep	Mature female	5.34	5.00	14.00
	Young (<1 yr)	7.42	3.05	7.42
	Other	3.05	3.05	9.00
Goats	Mature female	4.62	4.62	9.00
	Young (<1 yr)	6.72	2.90	6.72
	Other	2.90	2.90	5.00
Swine	Not divided	1.00	1.00	1.00
Slaughtered	Cattle and buffalo	58.43	52.50	58.43
	Sheep and goat	3.09	3.09	5.16
	Swine	2.53	2.53	3.67

Emission factors series:

IPCC, 1996

IPCC, 2006

Yamaji et al., 2003

Verburg & Vandergon, 2001

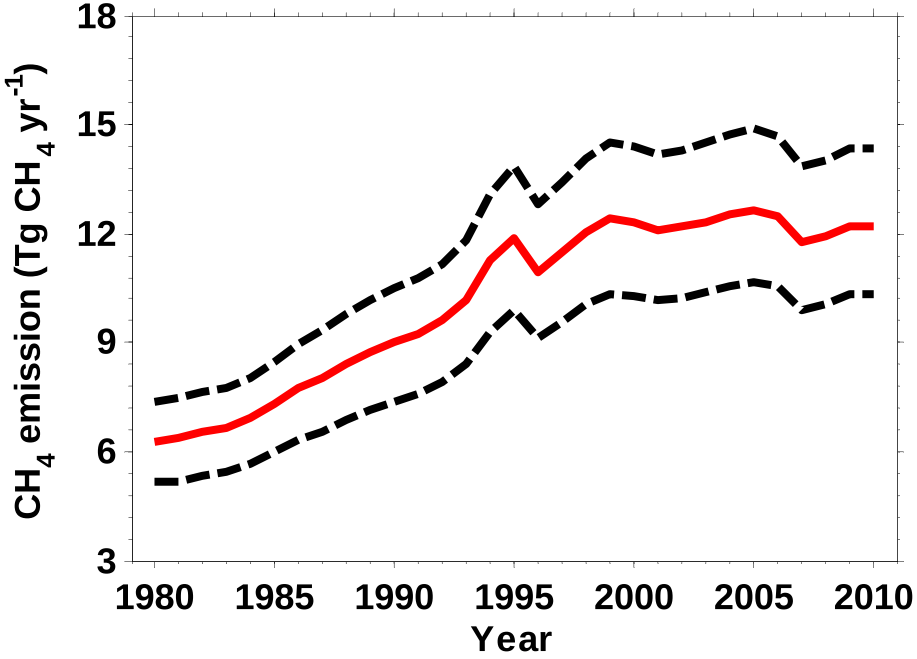
Khalil et al., 1993

Dong et al., 2004

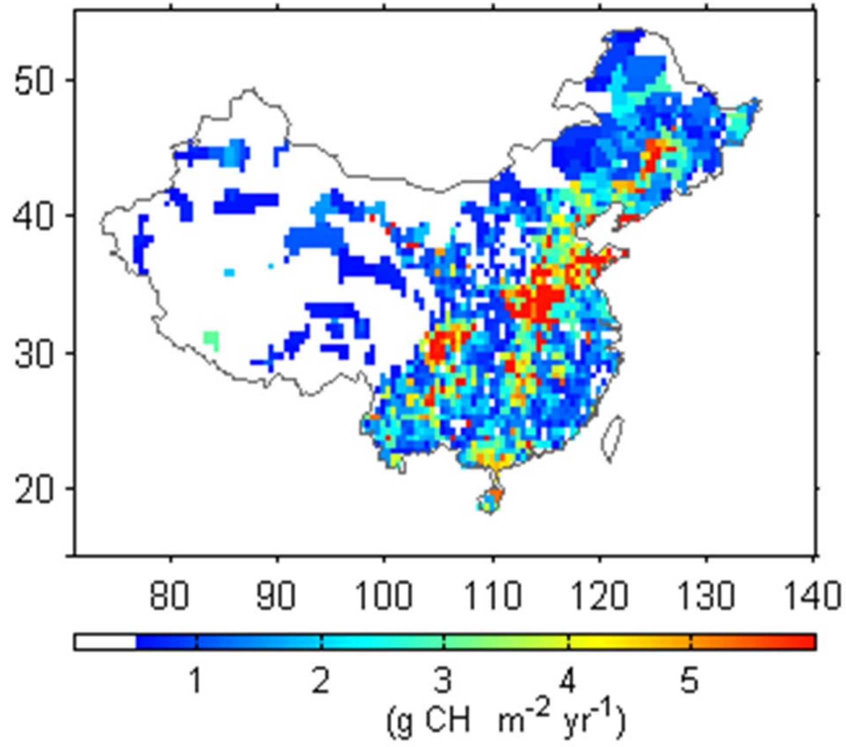
Zhang et al., 2007

CH_4 emissions from livestock

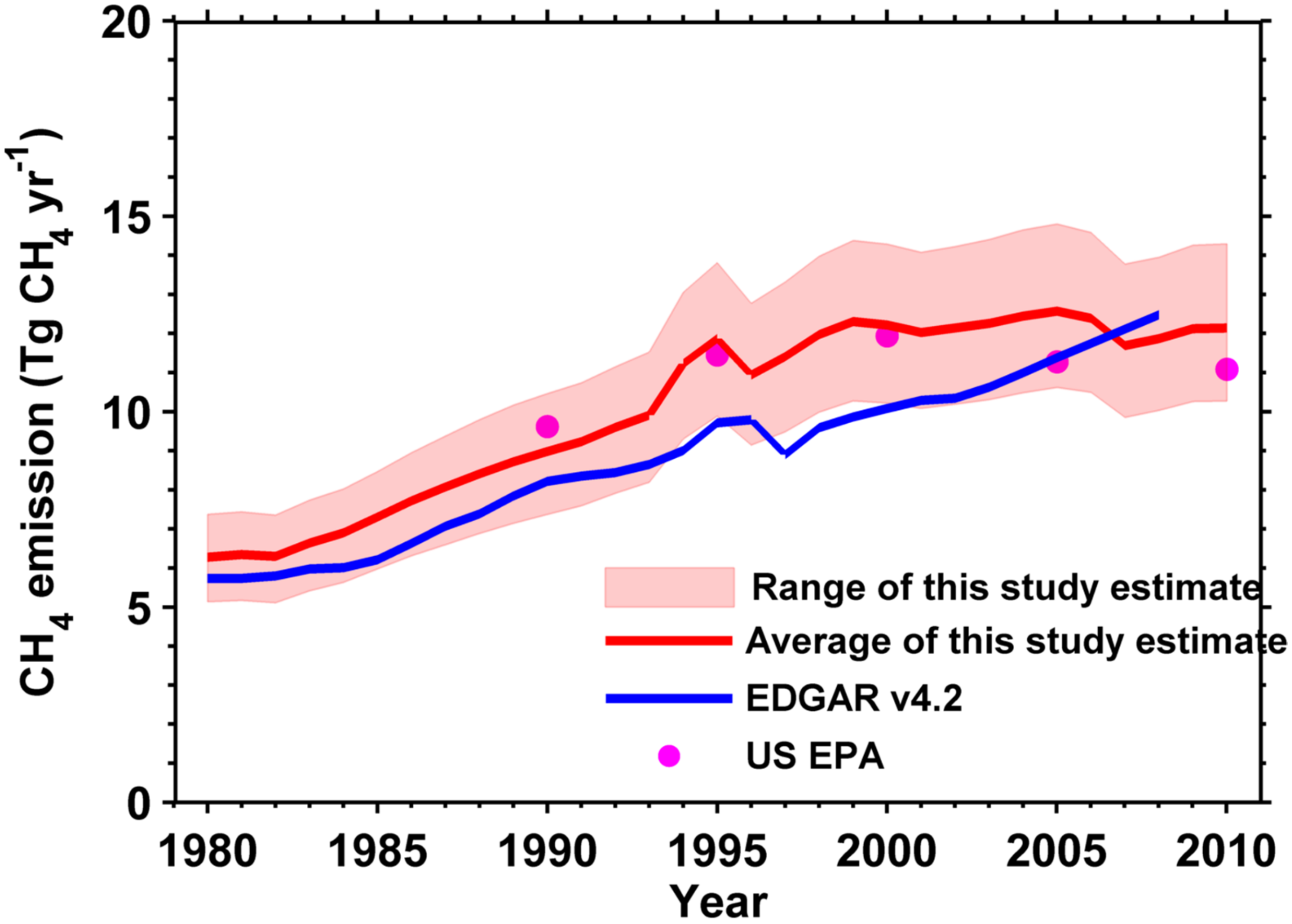
Interannual variation



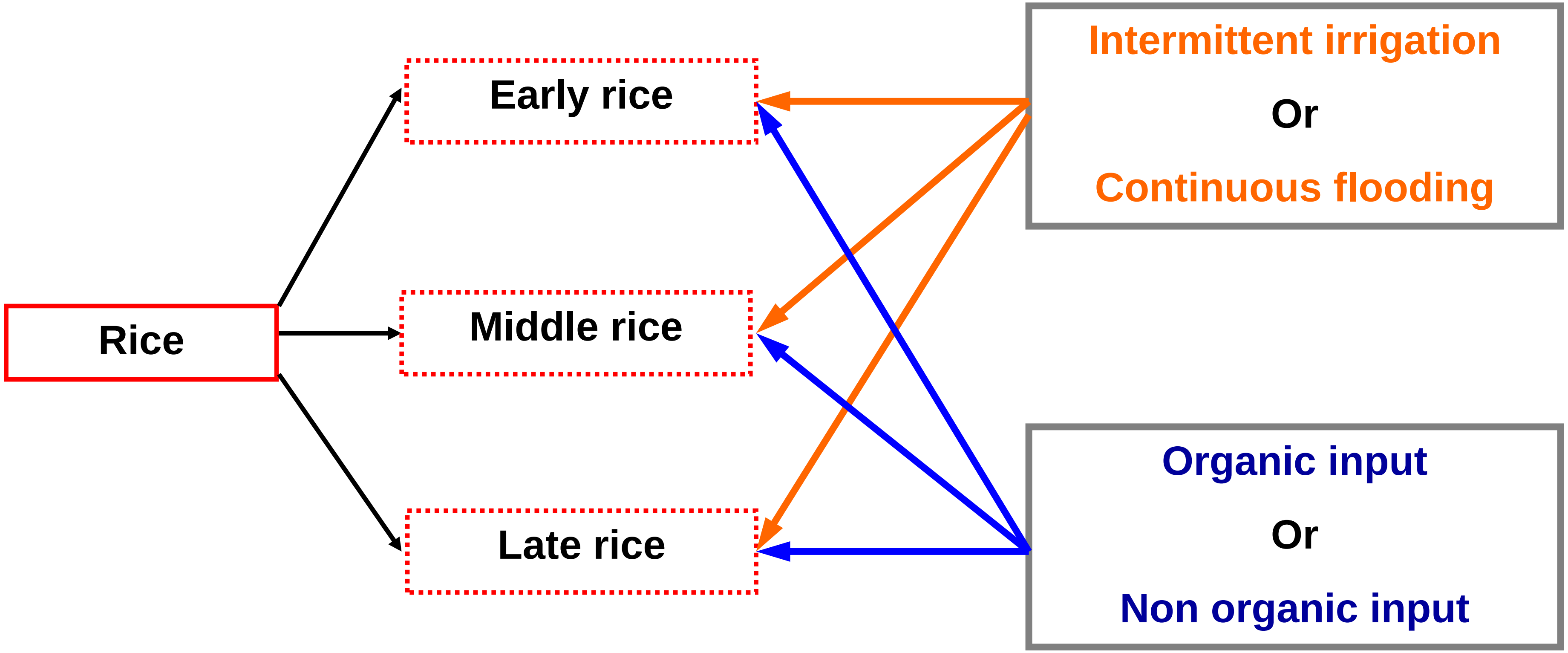
Spatial patterns



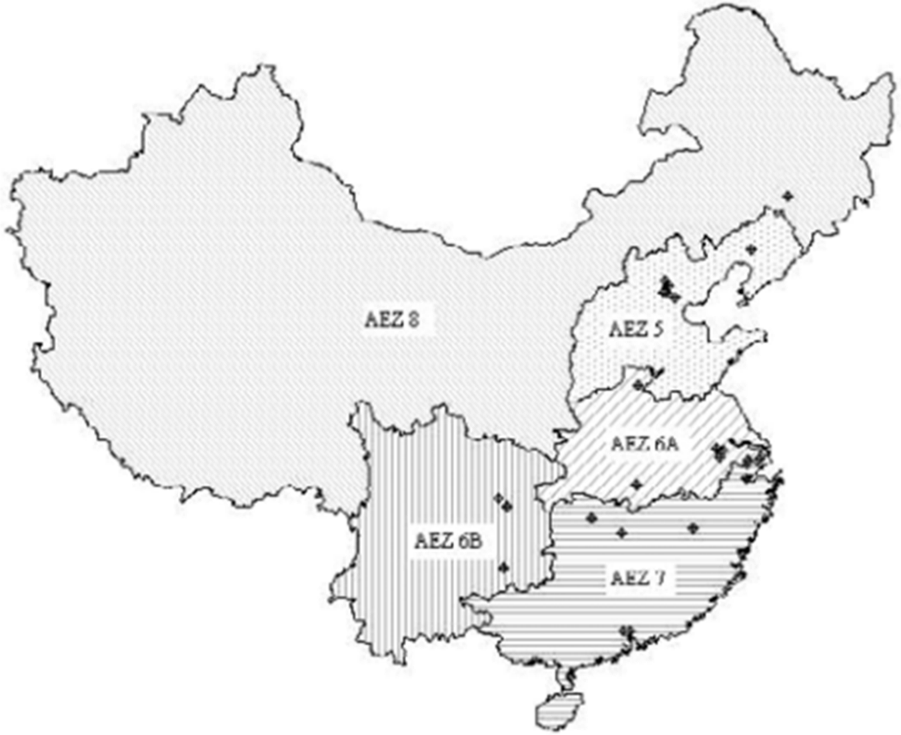
CH_4 emissions from livestock



CH_4 emissions from rice cultivation



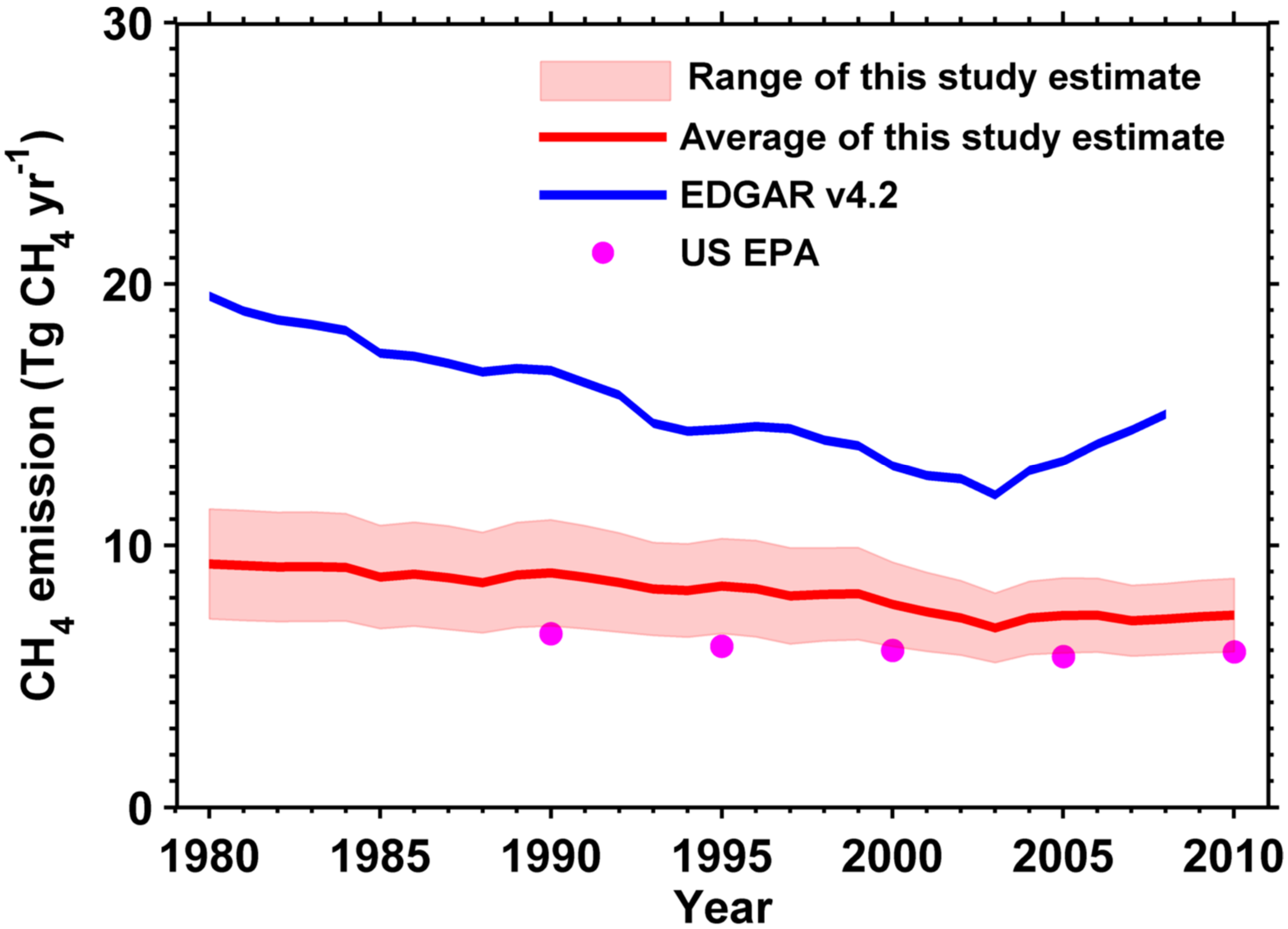
CH_4 emissions factors of rice cultivation



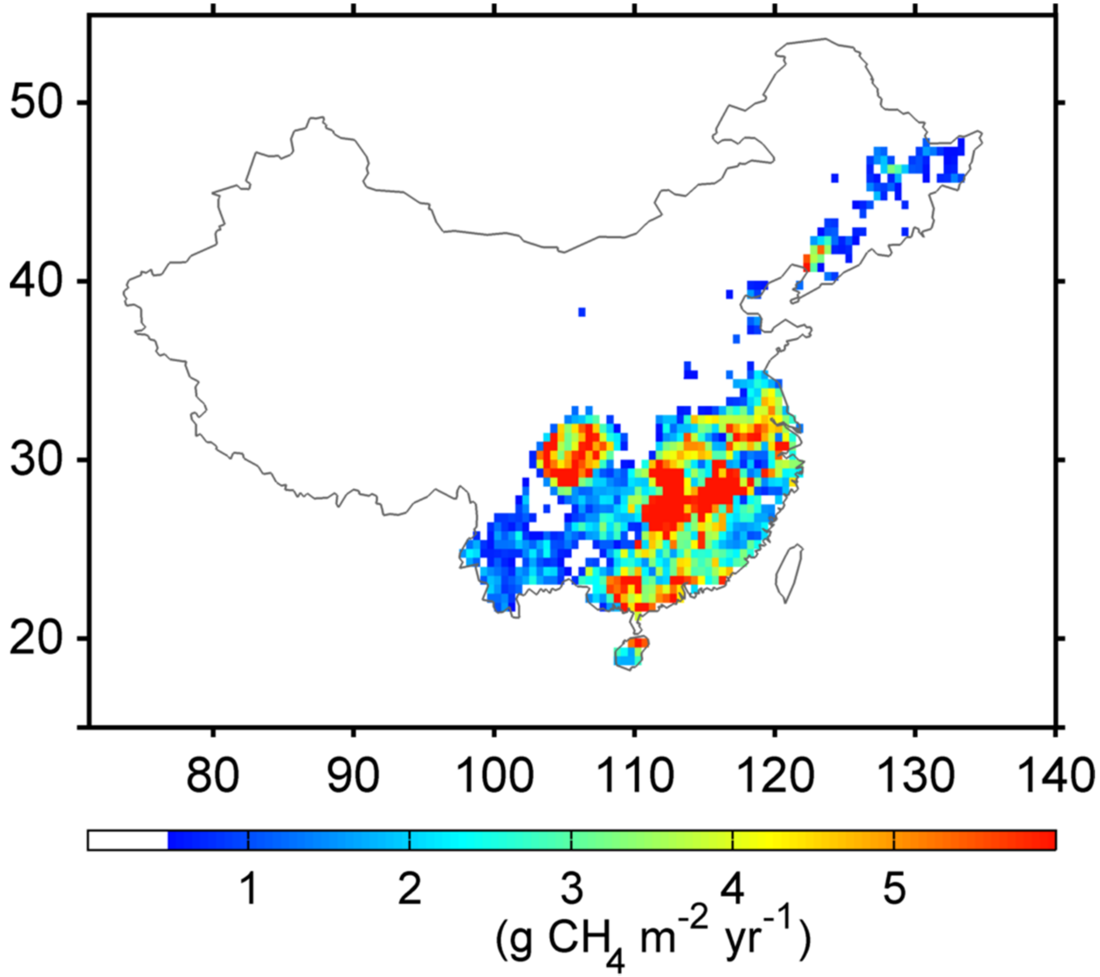
23 sites, 204 treatment measurements

Yan et al., JGR, (2003)

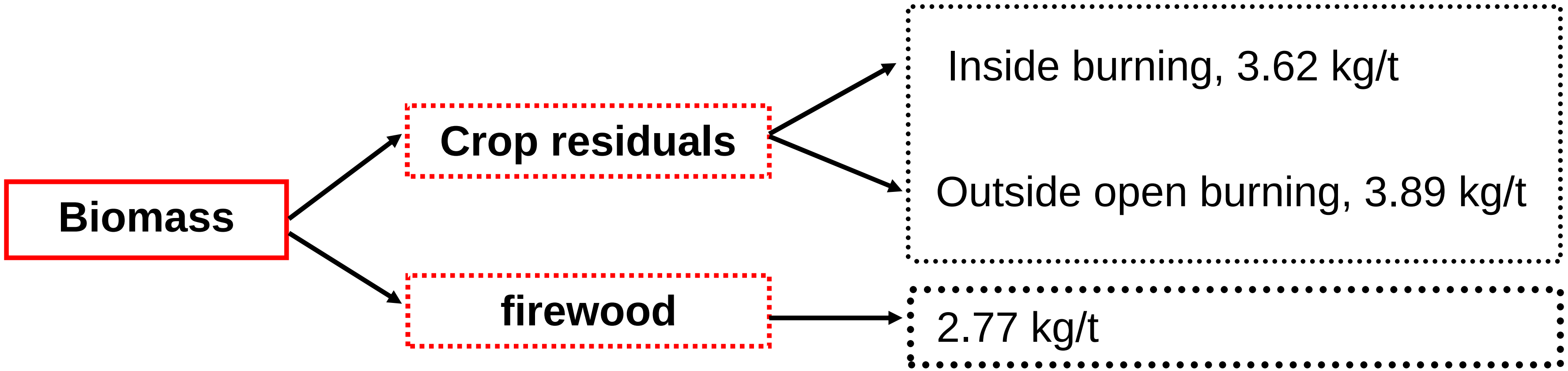
CH_4 emissions from rice cultivation



Spatial patterns of CH_4 emissions from rice cultivation

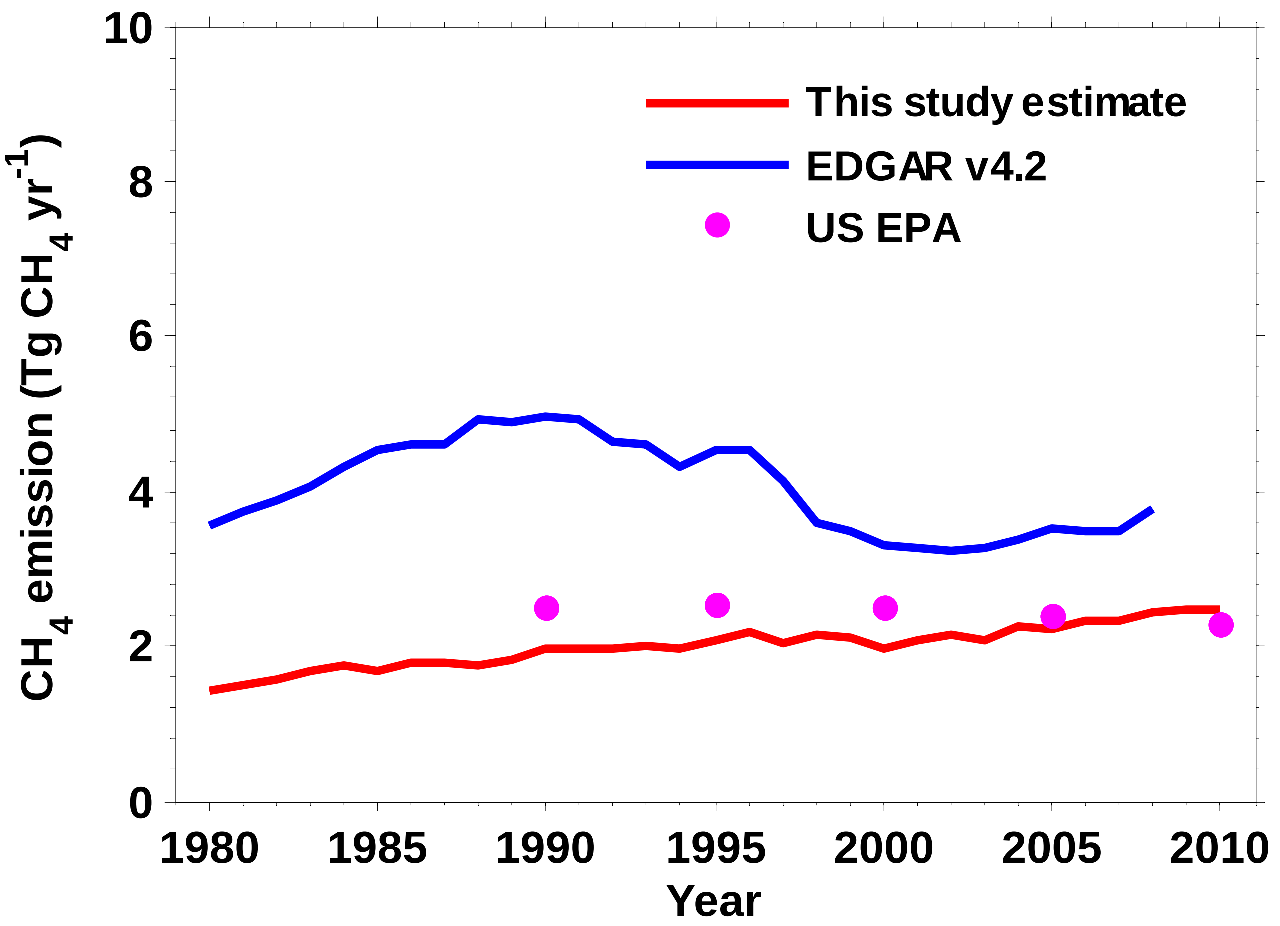


CH_4 emissions from biomass burning



Tian et al., (2011), in Chinese

CH_4 emissions from biomass burning



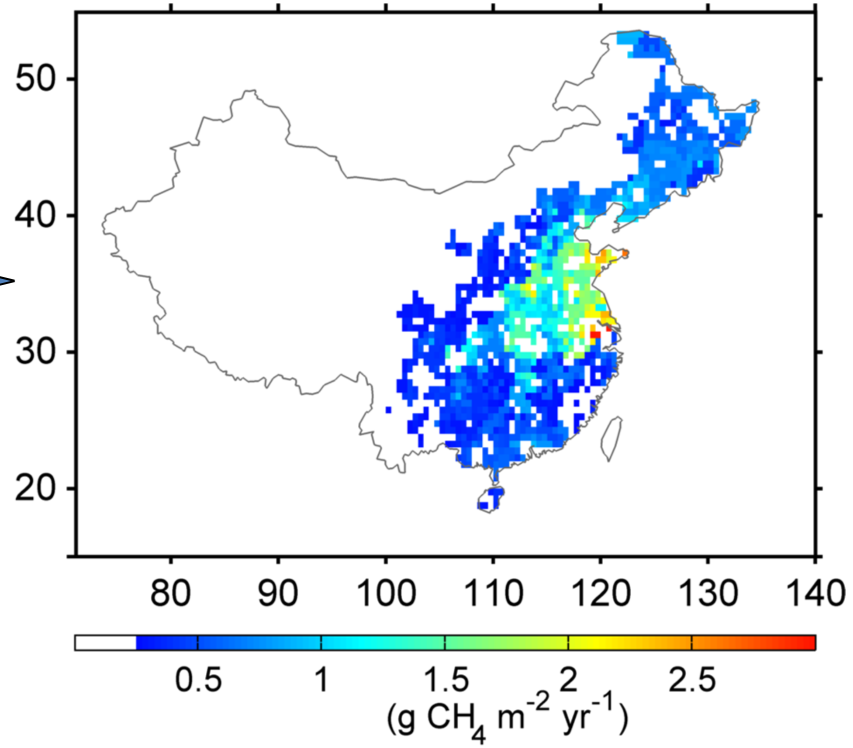
Spatial patterns of CH_4 emissions from biomass burning

Province statistics data

Rural population

Interpolation

0.5° × 0.5° grid



CH_4 emissions from waste

- ✓ **Municipal solid waste**
- ✓ **Domestic sewage**
- ✓ **Industrial wastewater**

CH_4 emissions from solid waste

METHANE EMISSIONS

The CH_4 emissions from solid waste disposal for a single year can be estimated using Equations 3.1. CH_4 is generated as a result of degradation of organic material under anaerobic conditions. Part of the CH_4 generated is oxidised in the cover of the SWDS, or can be recovered for energy or flaring. The CH_4 actually emitted from the SWDS will hence be smaller than the amount generated.

EQUATION 3.1
CH_4 EMISSION FROM SWDS

$$CH_4\ Emissions = \left[\sum_x CH_4\ generated_{x,T} - R_T\right] \bullet (1 - OX_T)$$

Where:

CH_4 Emissions = CH_4 emitted in year T, Gg

T = inventory year

x = waste category or type/material

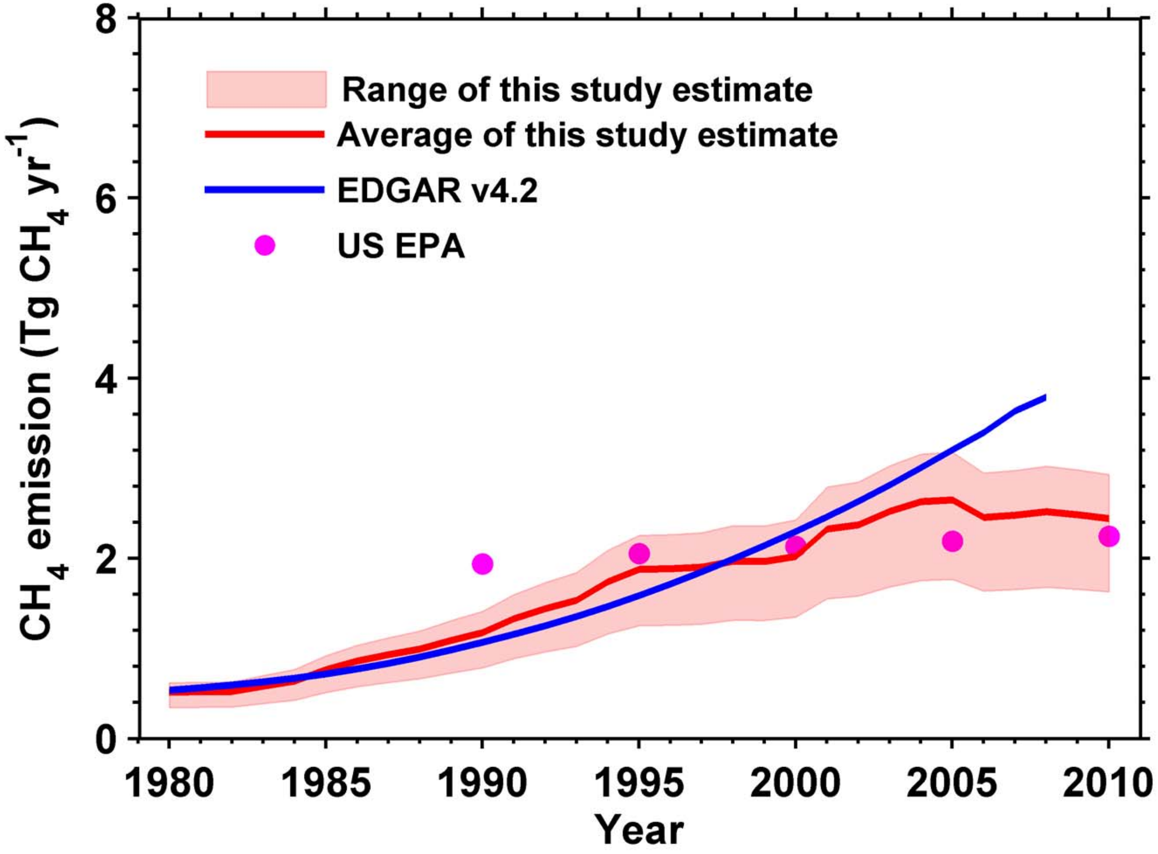
R_T = recovered CH_4 in year T, Gg

OX_T = oxidation factor in year T, (fraction)

The CH_4 recovered must be subtracted from the amount CH_4 generated. Only the fraction of CH_4 that is not recovered will be subject to oxidation in the SWDS cover layer.

IPCC, (2006)

CH_4 emissions from solid waste

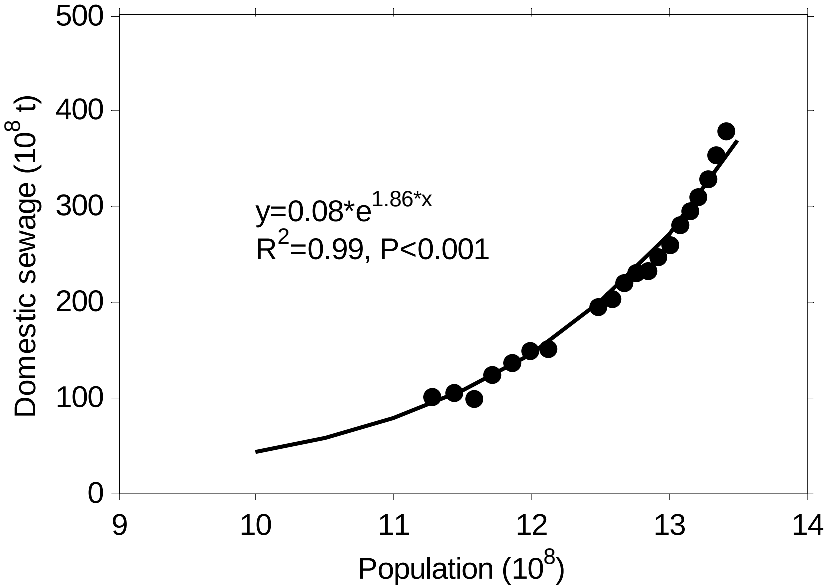


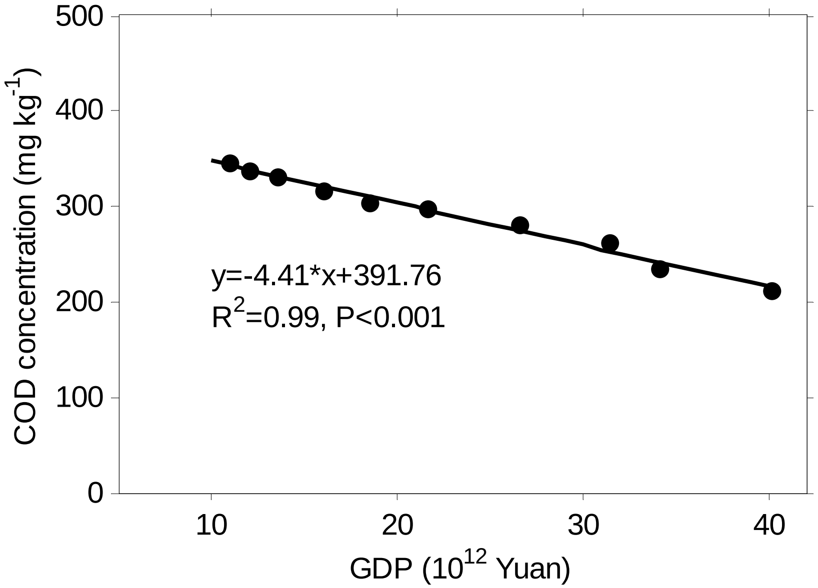
Emission factor from Gao et al., (2006) and IPCC, (2006)

CH_4 emissions from domostic sewage

Domestic sewage exponentially increase with population,

but COD decrease with economics development

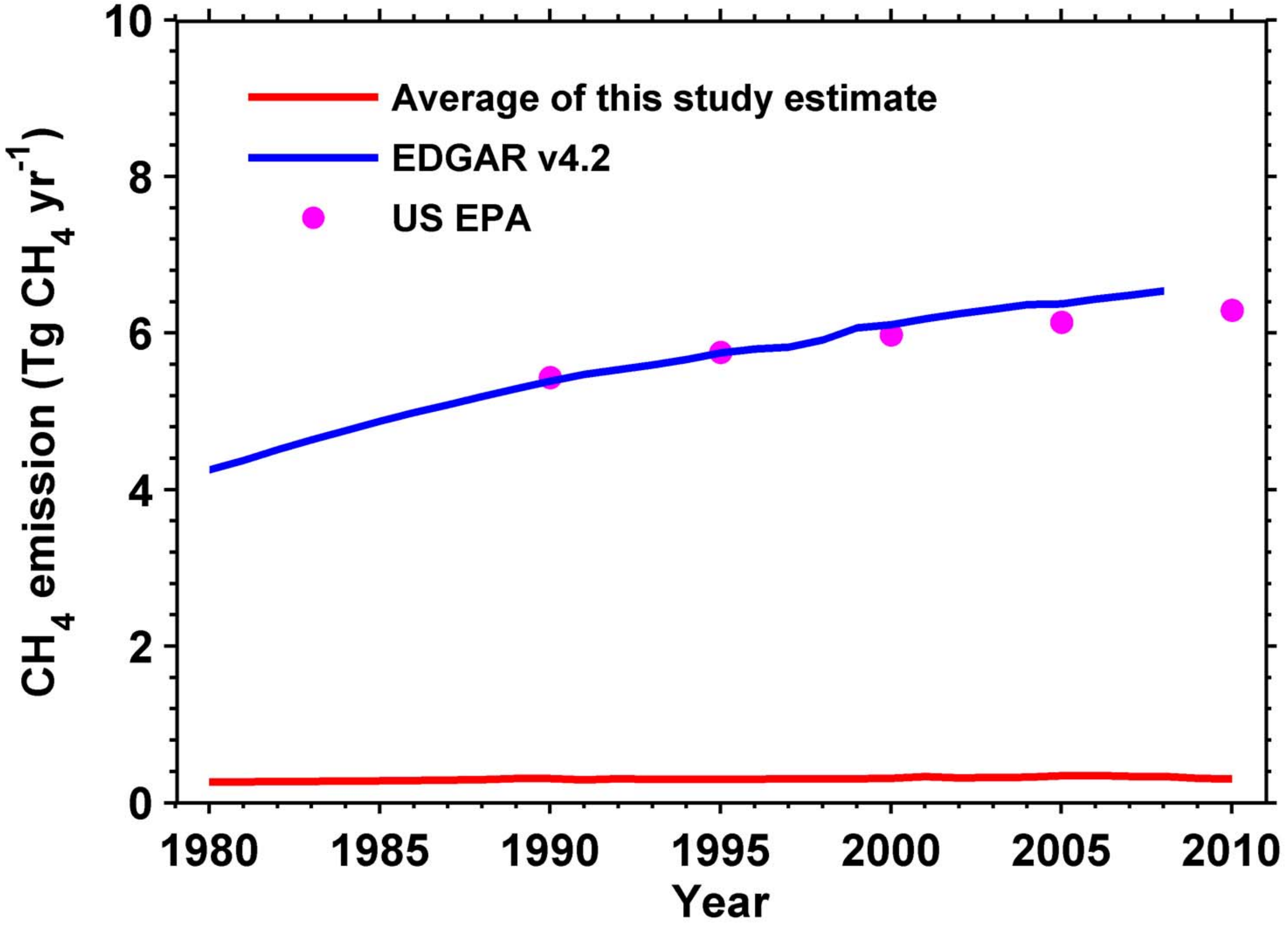




CH4 emission = Domestic sewage * COD * 0.25 kg CH4/kg COD * Methane correction factor (0.1)

Emission factor from IPCC, (2006)

CH_4 emissions from wastewater



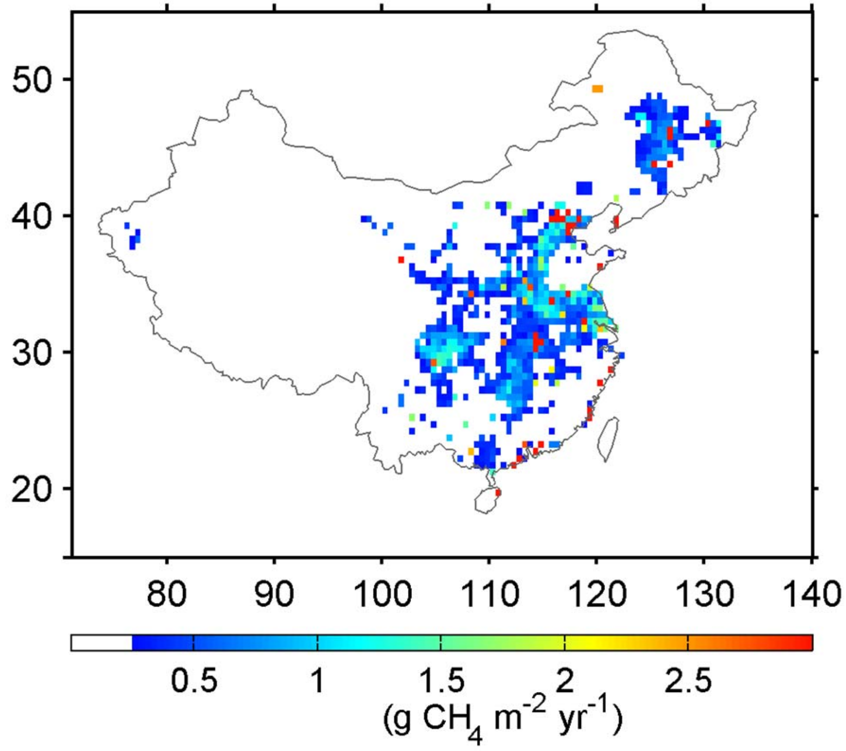
Spatial patterns of CH_4 emissions from waste

Province statistics data

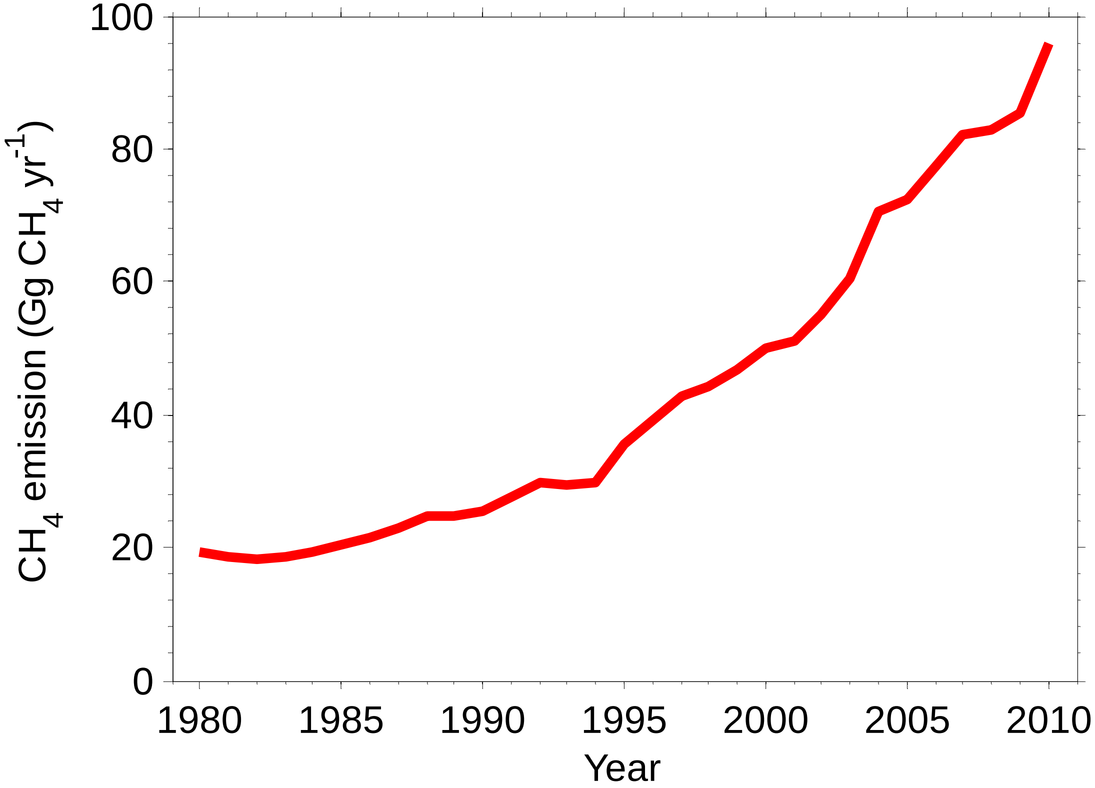
County level Population, GDP

Interpolation

0.5° ×0.5°

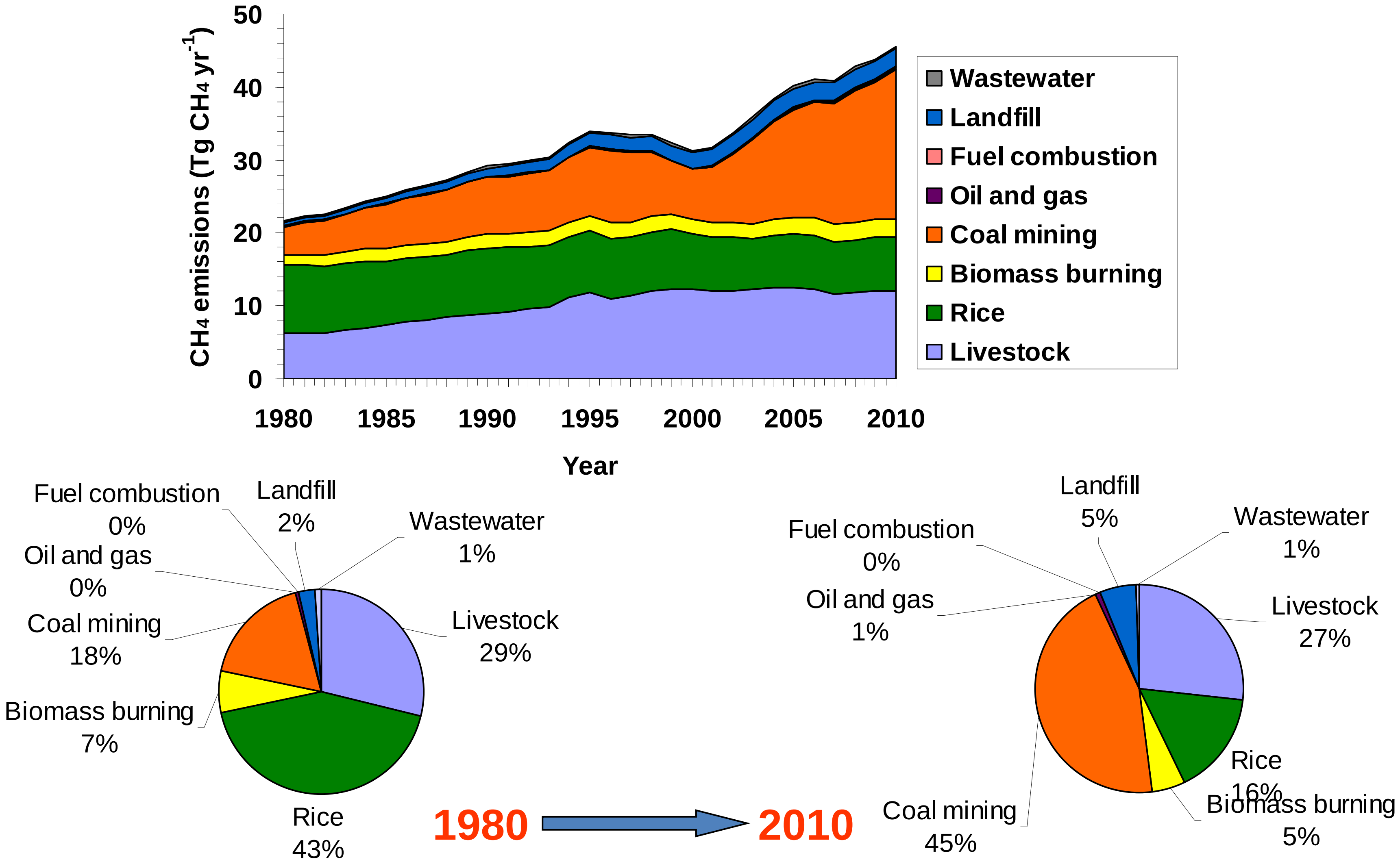


CH_4 emissions from fossil fuel combustion



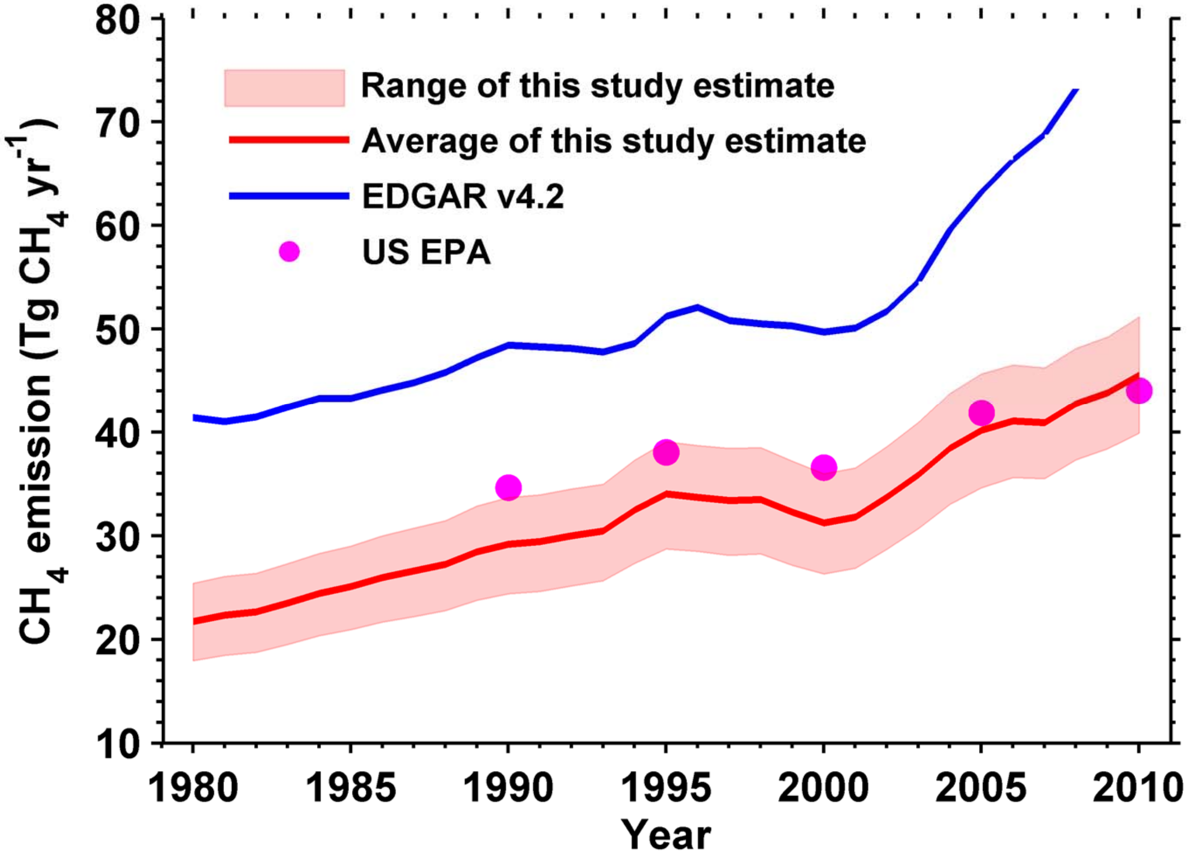
Less than 0.5% of total CH_4 emissions

Summary



50
40
30
20
10
0
CH4 emissions (Tg CH4 yr-1)
1980
1985
1990
1995
2000
2005
2010
Year
Wastewater
Landfill
Fuel combustion
Oil and gas
Coal mining
Biomass burning
Rice
Livestock
Fuel combustion 0%
Landfill 2%
Wastewater 1%
Oil and gas 0%
Coal mining 18%
Livestock 29%
Biomass burning 7%
Rice 43%
1980
2010
Landfill 5%
Wastewater 1%
Fuel combustion 0%
Oil and gas 1%
Livestock 27%
Rice 16%
Biomass burning 5%
Coal mining 45%

Summary



Range of this study estimate
Average of this study estimate
EDGAR v4.2
US EPA
CH_4 emission (Tg CH_4 yr^{-1})
80
70
60
50
40
30
20
10
1980
1985
1990
1995
2000
2005
2010
Year