GHG Emissions from Indian Paddy Fields

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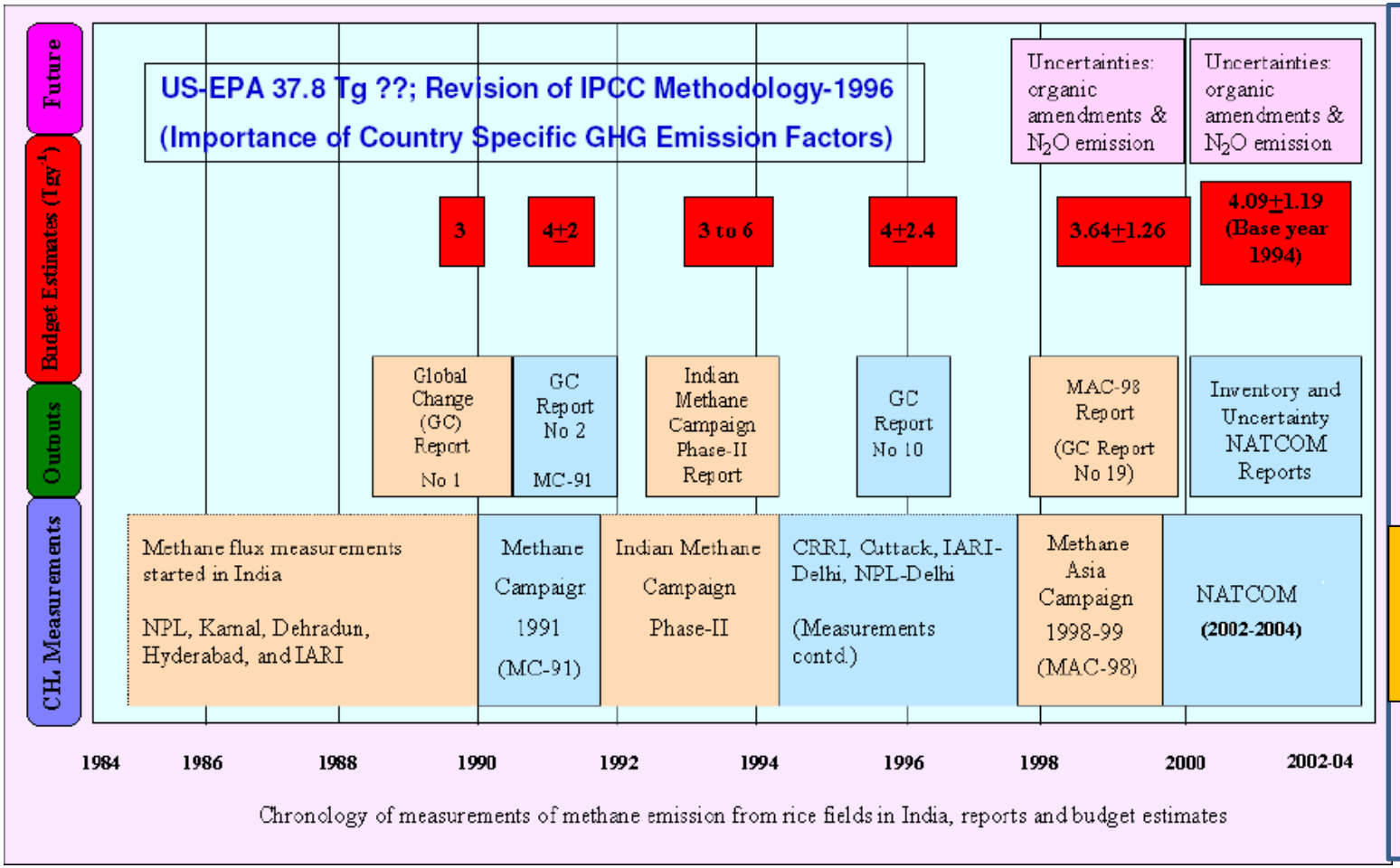
Chronology of Methane Budget Estimation in India



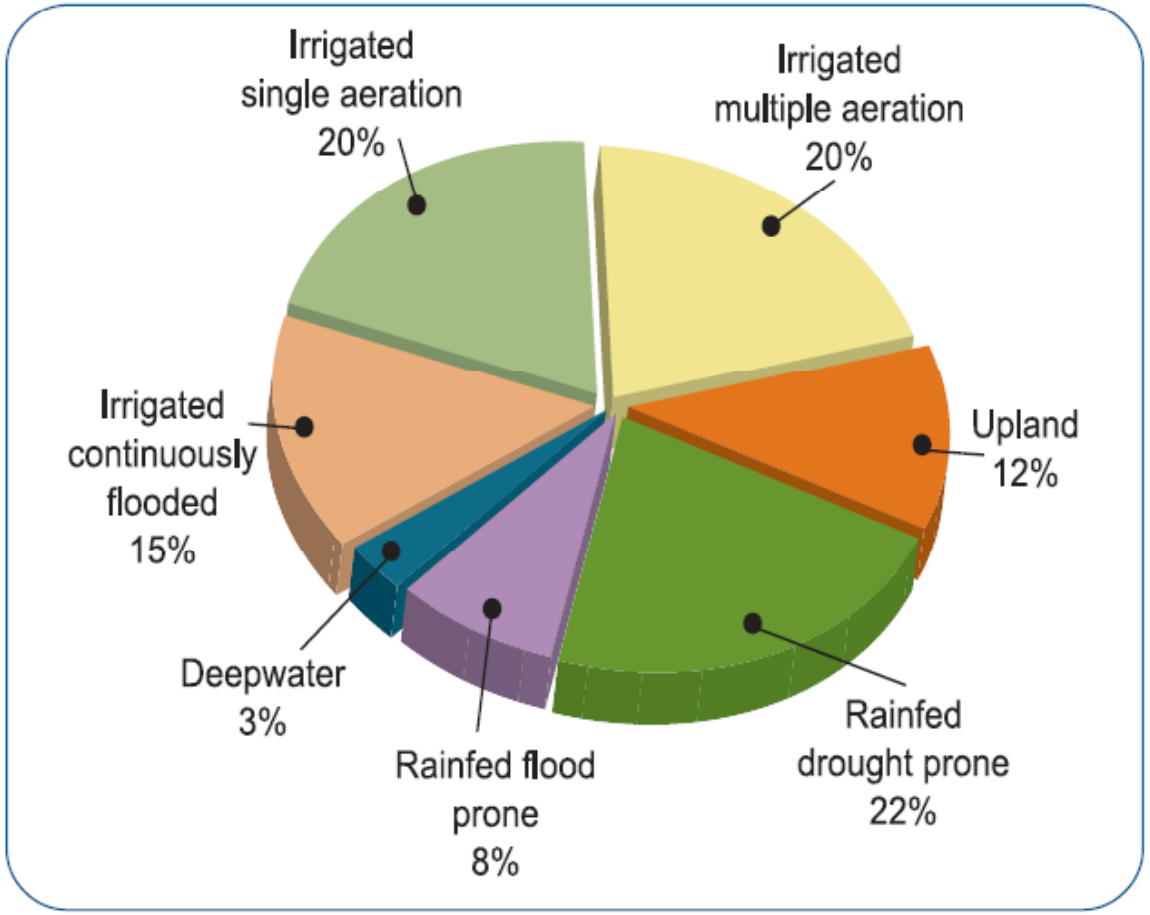
Chronology of measurements of methane emission from rice fields in India, reports and budget estimates

3.33 for 2007

INCCA Report, MoEF

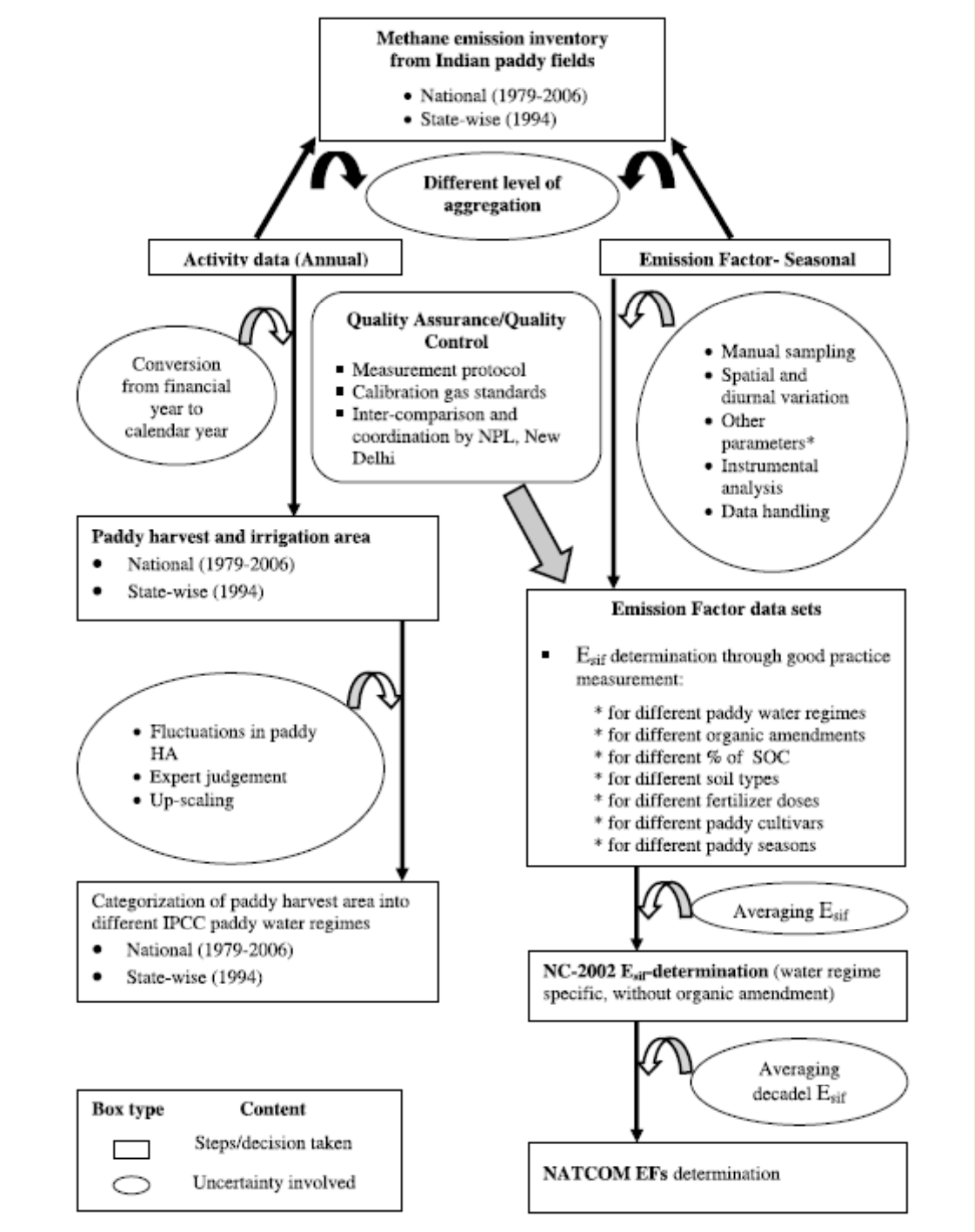
2010

Distribution of rice area under various water management practices in India in 2007



Source: INCCA 2010

methodology for methane emission inventory from Indian paddy fields during NATCOM-I



Gupta et. al., Chemosphere 2008

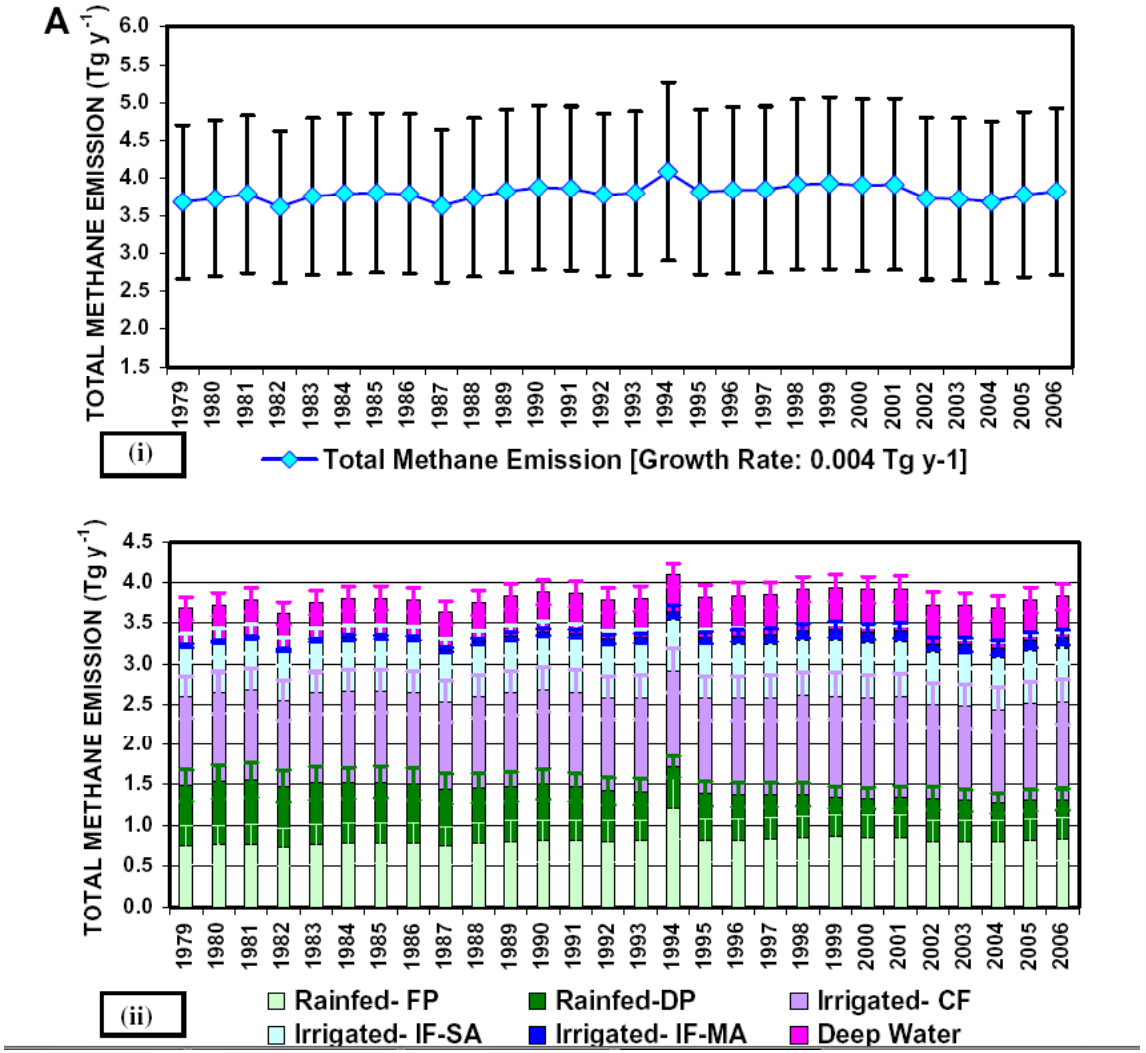
Chronology of Methane Emission Factor Development

Water regimes	RF-FP	RF-DP	IR-CF	IR-IF-SA	IR-IF-MA	DW
1991	19 ± 6.0# Koirapur	5 ± 3.2# Devoke,Cuttack	12.7 ± 1.6# Bhubaneswar, Cuttack, Chennai	5 ± 3.2# Devoke, Cuttack	0.56 ± 0.23# Allahabad, Faizabad, NPL	19 ± 6.0# Koirapur
1992			18.6 ± 9.3# Bhubaneswar			
1993					1.64 NPL	
1994					2.39 ± 0.8# IARI and NPL New Delhi	
1995			13.7 ± 2# Maruteru		1.82 ± 0.76# IARI and NPL New Delhi	
1996					2.05 IARI, New Delhi	
1997					1.48 IARI, New Delhi	
1998		8.7 ± 2.4# Pant Nagar and Karnal	16.1 ± 2.2# Chennai	8.7 ± 2.4# Pant Nagar and Karnal	5.36 Pant Nagar	
1999			21.25 ± 10.01# CRRI, BHU			
NC-2002		7.14 AAU	22.53 ± 10.26# IRPE, CRRI, AAU, AU	6.17 AU, NRSA	0.78 ± 0.70# NPL, IARI, Meerut, AU, RRLT, NRSA	
NATCOM EFs	19 ± 6#	6.95 ± 1.86#	17.48 ± 4#	6.62 ± 1.89#	2.01 ± 1.49#	19 ± 6#
IPCC-1996 default values	16	8	20	10	4	16
MAC-1998 EFs	19 ± 6#	6.9 ± 4.3#	15.3 ± 2.6#	6.9 ± 4.3#	2.2 ± 1.5#	19 ± 6#

*Low soil organic carbon and without organic amendments.
It is 'mean ± standard deviation' in the value (** ± **).

Gupta et. al.,
Chemosphere 2008

Methane emissions from Indian paddy fields from 1979 to 2006



Gupta et. al., Chemosphere 2008

Effect of SOC & cultivar variety on CH_4 emissions

Effect of SOC on E_{sif} during NC-2002			
SOC (%)	**N applied (kg ha^1)**	**E_{sif} g m^2**	**Enhancement Factor**
1.14	52.90	0.68	1.5
0.79	50.60	0.47	
0.75	55.20	0.55	
0.64	50.60	0.45	
Station: Farmer's field-Meerut- IARI; paddy water regime: IR-IF-MA; cultivar: Pusa 44			

Effect of Cultivar variety on E_{sif} during NC-2002		
Cultivar	**E_{sif} g m^2**	**Enhancement Factor**
Lalat	29.33	1.5
K-39	29.73	
Ratna	30.91	
IR-64	45.39	
Station: CRRI, Cuttack, Orissa; amendment: N: urea @ 120 Kg ha^{-1} in 3 equal split, P: SSP @ 60 Kg ha^{-1} at basal, K: MoP @ 60 Kg ha^{-1} at basal; paddy water regime: IR-CF; SOC: 0.87%		

Gupta et. al., Chemosphere 2008

Effect rice seasons (Kharif and Rabi) and organic amendments on CH_4 emissions

Effect of Seasons on E_{sif} during NC-2002			
Season	**SOC (%)**	**E_{sif} g m^2**	**Enhancement Factor**
Rabi	1.08	12.98	
Kharif	0.92	23.04	1.8
Station: IRPE, West Bengal; amendment: urea 160 Kg ha^{-1}, oil cake 300 Kg $^{-1}$, super phosphate 90 Kg $^{-1}$, potash 60 Kg $^{-1}$, DAP 120 Kg $^{-1}$; paddy water regime: IR-CF; cultivar: IET			

Effect of organic amendments on E_{sif} during NC-2002			
Organic Amendment	**E_{sif} g m^2 (IR MA)**	**E_{sif} g m^2 (IR SA)**	**Enhancement Factor**
With organic amendment	7.15	12.5	1.8
Without organic amendment	5.36	7.07	1.3
Enhancement Factor	1.3	1.8	
Pant Nagar, UP; amendment: NPK-60, 50, 40 Kg $^{-1}$, FYM @ 50% N; cultivar: Pant-4; season: Kharif, 1998			

Gupta et. al., Chemosphere 2008

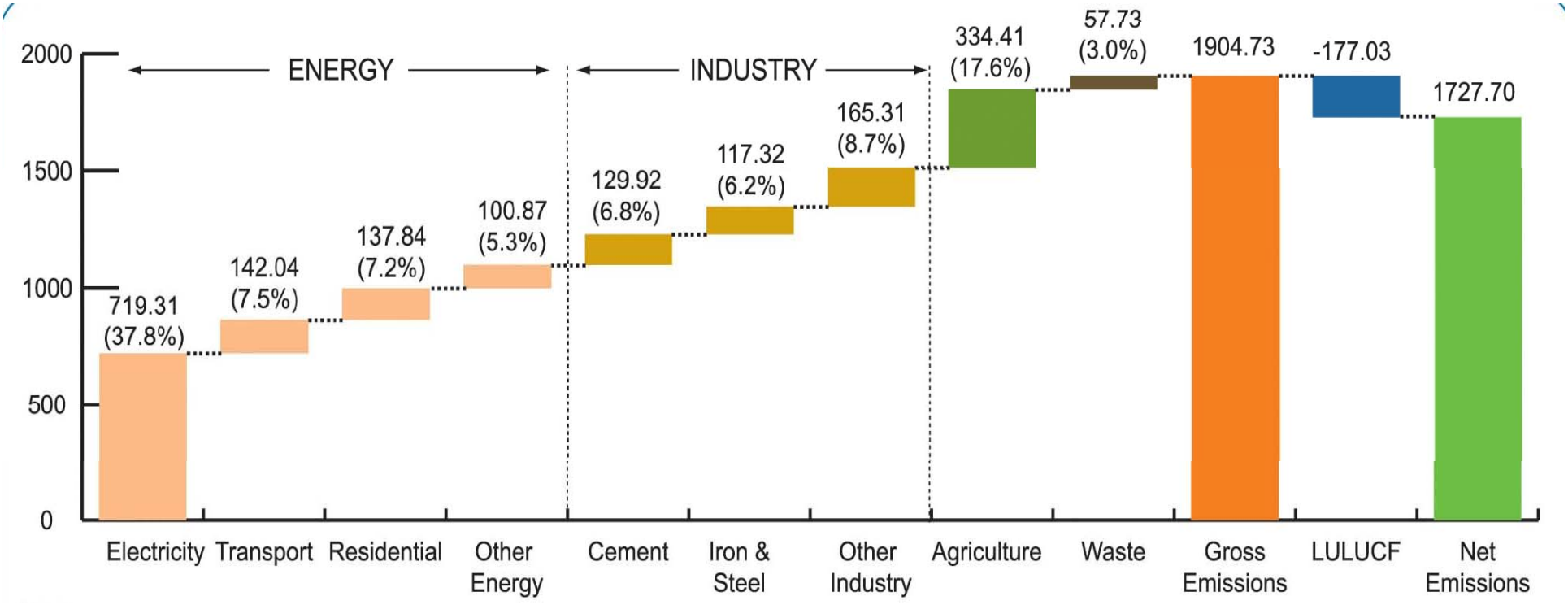
Effect of organic amendments on E_{sif} during MAC-1998

Water regime	E_{sif} g m^{-2}(no organic amendment)	E_{sif} g m^{-2}(with organic amendment)	Enhancement factor[$]
(i) For low organic carbon soils, <0.7%			
RF-FP	19 ± 6 (15)[*#]		
RF-DP	7 ± 4 (7)[*#]	13 (13)[*]	1.9 (1.9)[*]
IR-CF	15 ± 3 (12)[*#]	12 ± 4 (16)[*#]	0.8 (1.3)[*]
IR-IF-SA	7 ± 4 (9)[*#]	13 (13)[*]	1.9 (1.4)[*]
IR-IF-MA	2 ± 1 (2)[*#]	5 (8)[*]	2.5 (4)[*]
DW	19 ± 6 (19)[*#]	(26)[*]	(1.4)[*]
(ii) For high organic carbon soils, >0.7%			
RF-FP		(30)[*]	
RF-DP	8 ± 2 (8)[*#]		
IR-CF	26 ± 7 (29)[*#]	63 ± 17 (60)[*#]	2.4 (2)[*]
IR-IF-SA	8 ± 2 (8)[*#]	(19)[*]	(2.4)[*]
IR-IF-MA	(6)[*]	(21)[*]	(3.5)[*]

[$] It is the ratio of the maximum emission (E_{sif} g m^{-2}) to the minimum emission.
[*] MAC-1998 synthesized values for Asia.
[#] It is 'Mean ± standard deviation' in the value (** ± **).

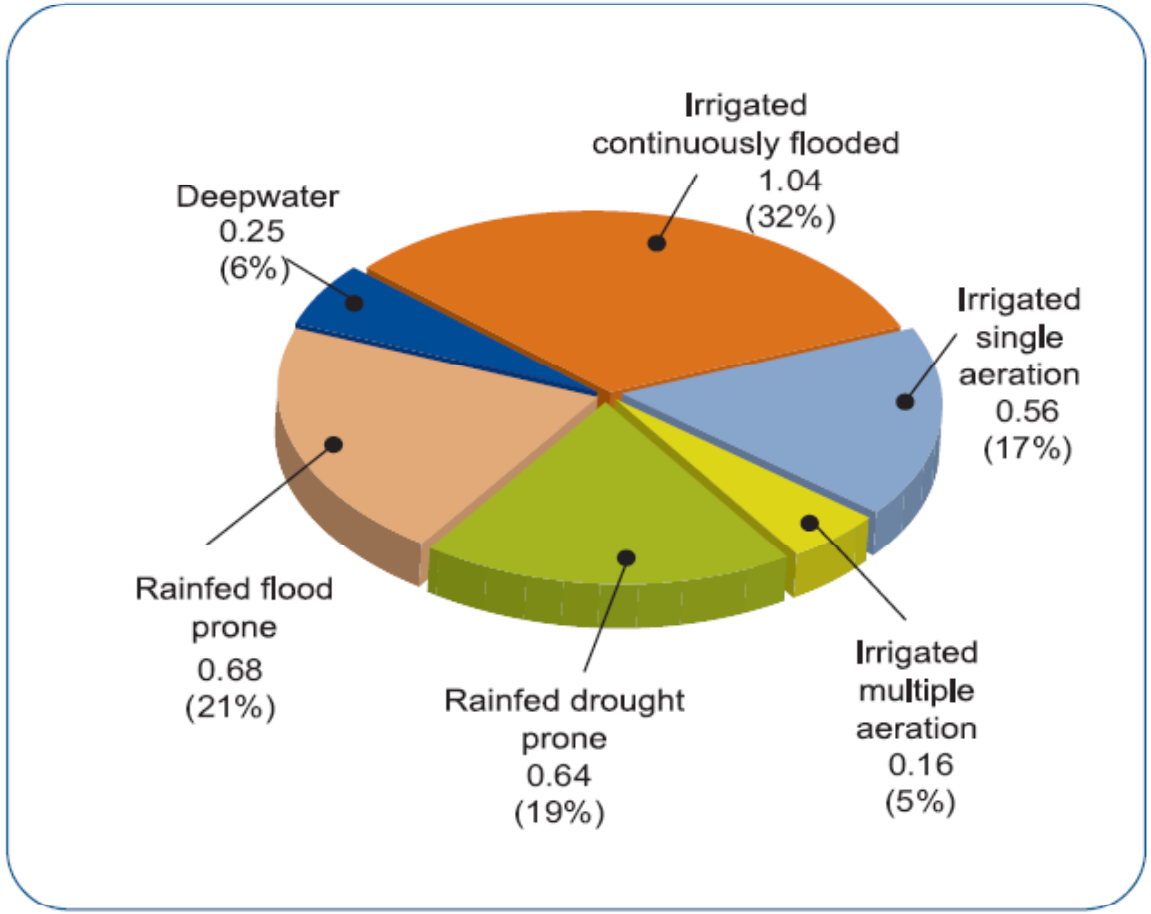
Gupta et. al., Chemosphere 2008

GHG Emissions by Sector 2007 (in CO_2 equivalent)



Source: INCCA 2010

CH_4 emission contribution (in million tons) from different rice ecosystems in India in 2007



Total Emission – 3.327 million tons

Source: INCCA 2010

A comparison of GHG emissions by sector between 1994 & 2007

(in million tons of CO_2 eq)

	1994		2007		CAGR (%)
Electricity	355.03	(28.4%)	719.30	(37.8%)	5.6
Transport	80.28	(6.4%)	142.04	(7.5%)	4.5
Residential	78.89	(6.3%)	137.84	(7.2%)	4.4
Other Energy	78.93	(6.3%)	100.87	(5.3%)	1.9
Cement	60.87	(4.9%)	129.92	(6.8%)	6.0
Iron & Steel	90.53	(7.2%)	117.32	(6.2%)	2.0
Other Industry	125.41	(10.0%)	165.31	(8.7%)	2.2
Agriculture	344.48	(27.6%)	334.41	(17.6%)	-0.2
Waste	23.23	(1.9%)	57.73	(3.0%)	7.3
Total without LULUCF	1251.95		1904.73		3.3
LULUCF	14.29		-177.03		
Total with LULUCF	1228.54		1727.71		2.9

Note: Figure in brackets indicate percentage emissions from each sector with respect to total GHG emissions without LULUCF in 1994 and 2007 respectively

Source: INCCA 2010

Methane emission from rice cultivation in 2007 (INCCA -2010)

Ecosystem	Water regime	Rice Area 2007 (000′ ha)	Emission Coeff. 2007 (kg ha^{-1})	Methane ('000 tons)
Irrigated	CF*	6427	162	1042
	SA	8517	66	562.1
	MA	8898	18	160.1
Rainfed	DP	3577	70	635
	FP	9640	190	679
Deep water	DW	1309	190	249
Upland		5234	0	0
Total				**3327**

Note: *CF - Continuously flooded*
SA - Single Aeration
MA - Multiple Aeration
DP - Drought Prone
FP - Flood Prone

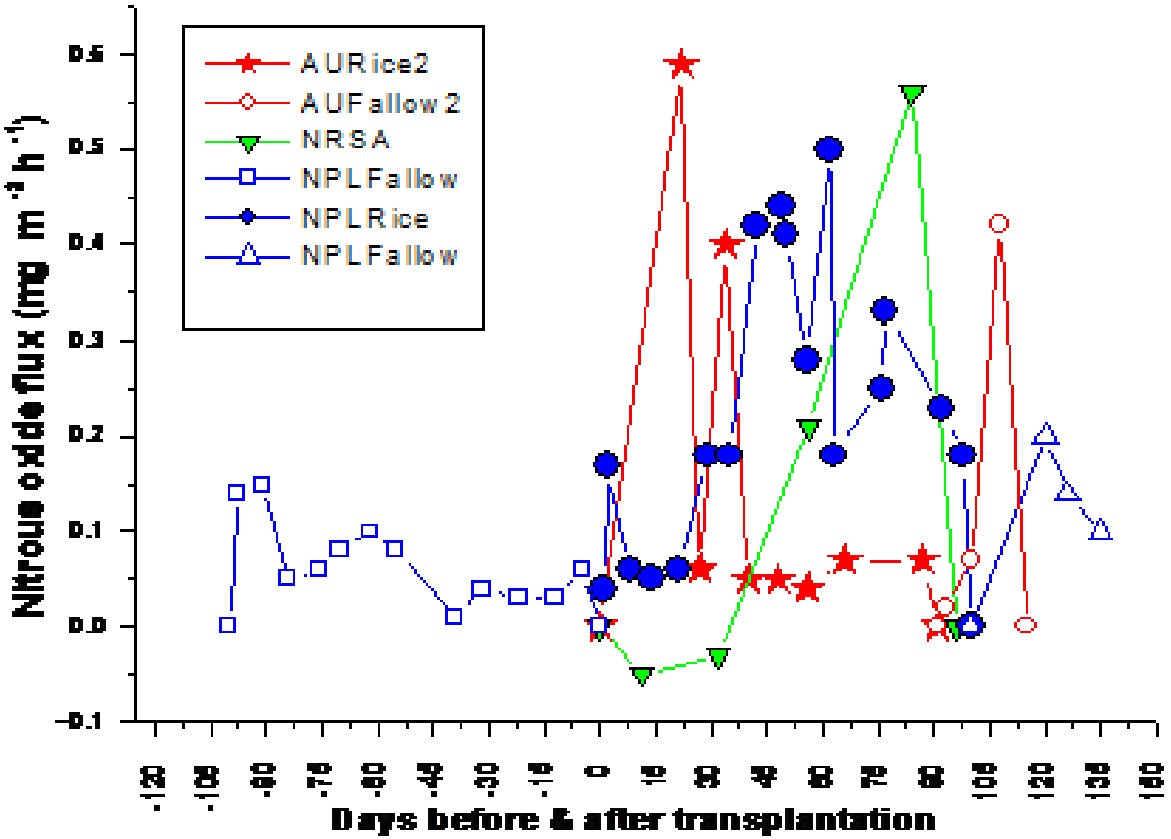
NATCOM-I EFs (2004)	
Water Regime	Emission Coefficient 2004 (kg/ha)
CF	174.8±40
SA	66.2± 18.9
MA	20.1± 14.9
DP	69.5± 18.6
FP	190±60
DW	190±60
Upland	0

Source: INCCA 2010 & Gupta et. al., Chemosphere 2008

Key categories

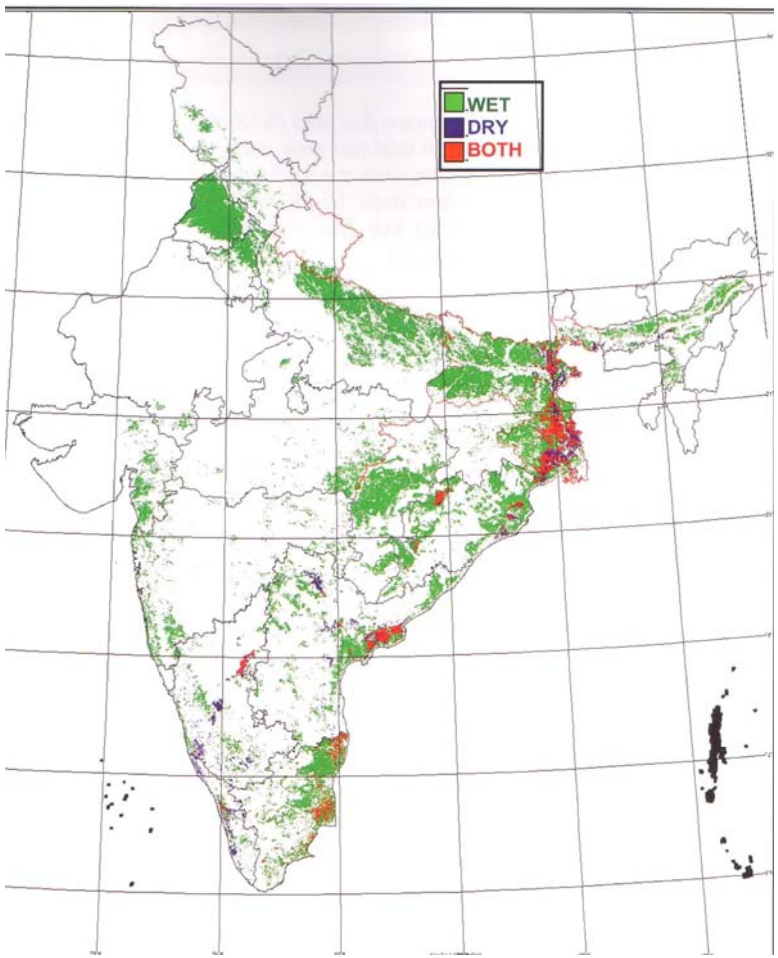
	CO_2 eq	Cumulative CO_2 eq	% of total	Tier Used	Emission factors used
Electricity generation	719305.34	719305.34	37.12065	Tier II	CS+D
Enteric fermentation	212095.8	931401.14	48.06611	Tier III	CS+D
Residential	137838.487	1069239.627	55.17944	Tier I	D
Cement production	129920	1199159.627	61.88412	Tier III	CS+D
Road transport	123554	1322713.627	68.26028	Tier II	CS+D
Iron & Steel production	117315.631	1440029.257	74.3145	Tier II	CS+D
Non-specific industries	88232.28	1528261.537	78.86784	Tier I	CS+D
Rice cultivation	69384	1597645.537	82.44849	Tier III	CS
Soils	43400	1641045.537	84.6882	Tier II	CS+D
Other energy industries	33845.32	1674890.857	86.43483	Tier I	CS+D
Agriculture/ Fisheries	33658.7	1708549.557	88.17183	Tier I	CS+D
Fugitive emissions	31697.295	1740246.852	89.8076	Tier III	CS
Food processing	27717.25	1767964.102	91.23799	Tier I	CS+D
Domestic waste water	22980.47	1790944.572	92.42392	Tier I	D
Industrial waste water	22050	1812994.572	93.56184	Tier II	CS+D
Municipal Solid waste	12694.71	1825689.282	94.21697	Tier II	CS+D
Aviation	10210.9	1835900.182	94.74391	Tier I	D

Seasonal nitrous oxide flux from IR-IF-MA paddy water regimes in NRSA and seasonal nitrous oxide flux from IR-IF-MA paddy water regimes & fallow fields in NPL & AU.



Source: Personal communication

Rice Strata Map of India derived from Satellite Data



Source: ISRO Scientific Report No. SAC/AFEG/AMD/EIAA/SN/03/08

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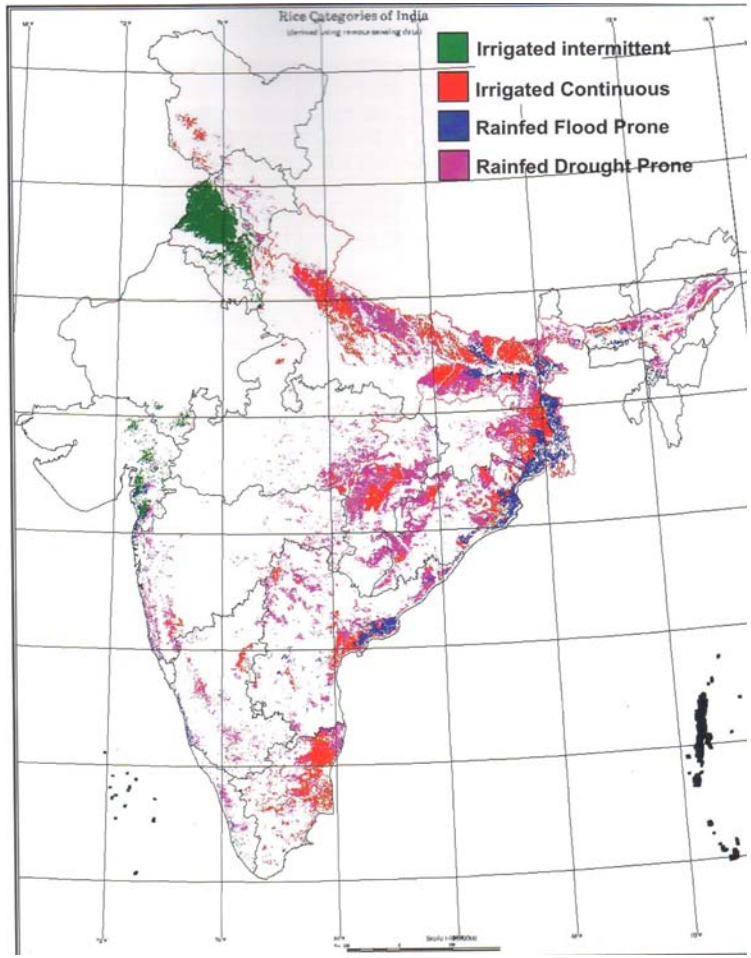

Source: ISRO Scientific Report No. SAC/AFEG/AMD/EIAA/SN/03/08

To conclude..

- Rice Paddy is a key source in national GHG emissions inventory
- Refinement in activity data and emission factors is important in reducing uncertainties
- Studies are underway to look for viable mitigation options for reducing the GHG emissions

Thanks