# Developing CH4 emission factors from rice cultivation in India - Triumphs and Challenges

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- National Inventory at a glace
- Importance of CH4 emission vis  a vis total national emissions
- CH4 emission measurements in India – Typical characteristics
- Emission factors derived
- Institutional Arrangements
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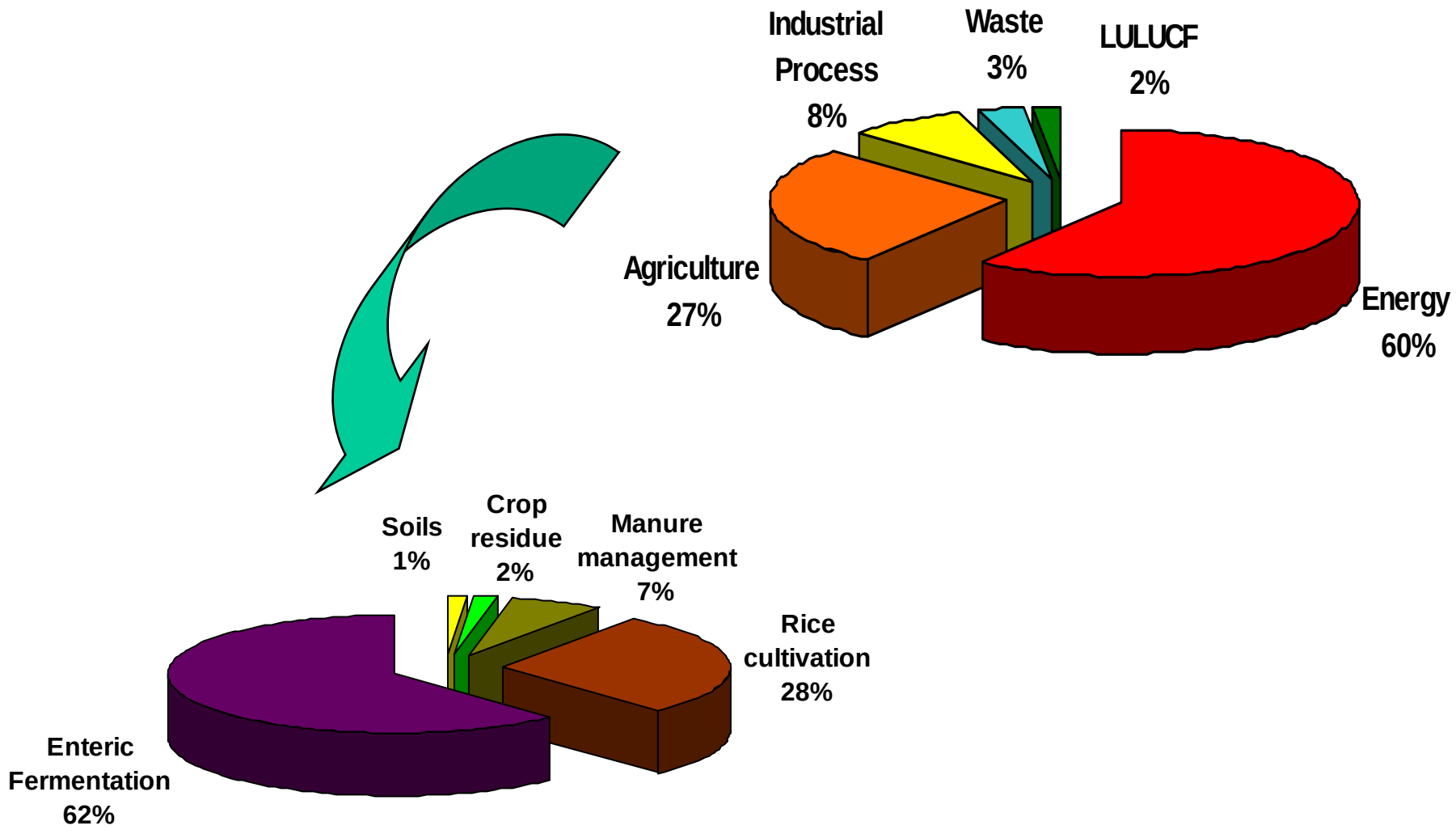
- Achievements so far
- Challenges ahead

# GHG Emissions from Sources and Removals by Sinks - India 1994

| GHG source and sink categories (Gg per year) | $CO_2$ emissions | $CO_2$ removals | $CH_4$ | $N_2O$ | $CO_2$ eq. emissions* |
|---|---|---|---|---|---|
| Total (Net) National Emission | 817023 | 23533 | 18083 | 178 | 1228540 |
| | | | | | |
| 1. All Energy | 679470 | | 2896 | 11.4 | **743820** |
| 2. Industrial Processes | 99878 | | 2 | 9 | 102710 |
| 3. Agriculture | | | 14175 | 151 | 344485 |
| 4. Land use, Land-use change and Forestry* | 37675 | 23533 | 6.5 | 0.04 | 14292 |
| 5. Other sources as appropriate and to the extent possible | | | | | 0 |
| 5a. Waste | | | 1003 | 7 | 23233 |
| 5b. Emissions from Bunker fuels # | 3373 | | | | 3373 |

*Converted by using GWP indexed multipliers of 21 and 310 for converting $CH_4$ and $N_2O$ respectively.

# Sectoral Distribution of GHG emissions



# Key source analysis – Level Assessment (1994)

(CS: Country Specific EF, D: IPCC default EF, R: Improvement Required).

| Sources of emission | $CO_2$ equivalent (Gg) | Percentage of total emissions | Cumulative emission (Gg) | Cumulative emission vs. total emission (%) | Tier used | EF used | Status of EF envisaged in SNC |
|---|---|---|---|---|---|---|---|
| Energy and transformation industries | 355037 | 28.9 | 355037 | 28.9 | Tier II | CS | R |
| Enteric Fermentation | 188412 | 15.3 | 543449 | 44.2 | Tier II | CS | R |
| Industry | 150674 | 12.3 | 694123 | 56.5 | Tier I | D | D |
| **Rice Cultivation** | **85890** | **7.0** | **780013** | **63.5** | **Tier II** | **CS** | **R** |
| Transport | 80286 | 6.5 | 860299 | 70.0 | Tier I | CS | R |
| Emission from Soils | 45260 | 3.7 | 905559 | 73.7 | Tier I | D | CS |
| Iron and steel production | 44445 | 3.6 | 950004 | 77.3 | Tier I | D | CS |
| Energy use in Residential sector | 43918 | 3.6 | 993922 | 80.9 | Tier I | D | D |
| Biomass burnt for energy | 34976 | 2.8 | 1028898 | 83.7 | Tier I | D | D |
| All other energy sectors | 32087 | 2.6 | 1060985 | 86.4 | Tier I | D | D |
| Cement production | 30767 | 2.5 | 1091752 | 88.9 | Tier I | CS | R |
| Energy consumed in Commercial/institutional | 20571 | 1.7 | 1112323 | 90.5 | Tier I | D | D |
| Manure Management | 20176 | 1.6 | 1132499 | 92.2 | Tier I | D | D |
| Ammonia production | 14395 | 1.2 | 1146894 | 93.4 | Tier I | D | CS |
| Land-use, Land-use change & Forestry | 14292 | 1.2 | 1161186 | 94.5 | Tier I | D | CS |
| Coal mining | 13650 | 1.1 | 1174836 | 95.6 | Tier III | CS | CS |

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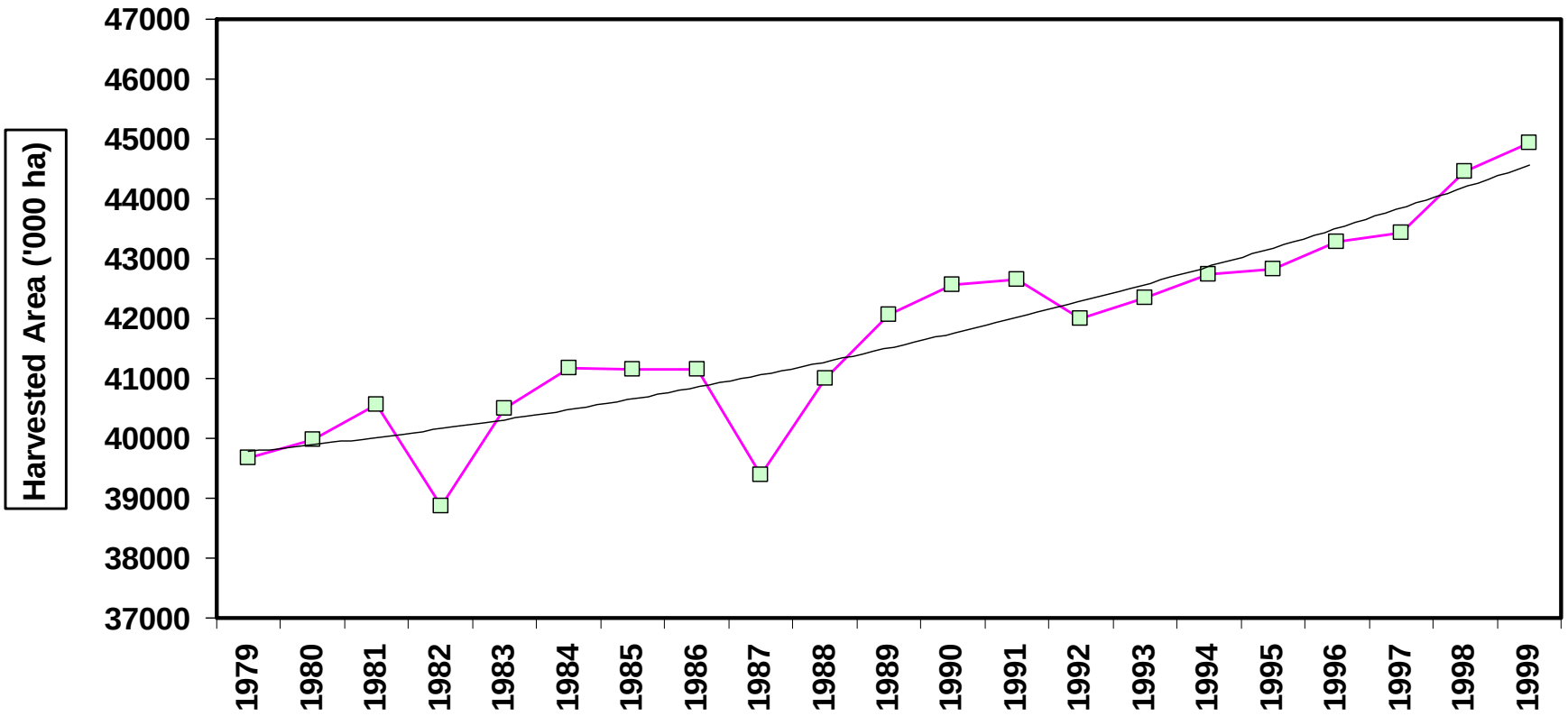
## (CS: Country Specific EF, D: IPCC default EF, R: Improvement Required).

| Sources of emission | $CO_2$ equivalent (Gg) | Percentage of total emissions | Cumulative emission (Gg) | Cumulative emission vs. total emission (%) | Tier used | EF used | Status of EF envisaged in SNC |
|---|---|---|---|---|---|---|---|
| Oil and natural gas system | 12621 | 1.0 | 1187457 | 96.7 | Tier I | D | D |
| Municipal Solid Waste Disposal | 12222 | 1.0 | 1199679 | 97.7 | Tier I | D | CS |
| Domestic Waste water | 7539 | 0.6 | 1207218 | 98.3 | Tier I | D | D |
| Lime stone and dolomite use | 5751 | 0.5 | 1212969 | 98.7 | Tier I | D | D |
| Agricultural crop residue | 4747 | 0.4 | 1217716 | 99.1 | Tier I | D | D |
| Nitric acid production | 2790 | 0.2 | 1220506 | 99.3 | Tier II | CS | CS |
| Human Sewage | 2170 | 0.2 | 1222676 | 99.5 | Tier I | D | D |
| Lime production | 1901 | 0.2 | 1224577 | 99.7 | Tier I | D | D |
| Industrial Waste Water | 1302 | 0.1 | 1225879 | 99.8 | Tier I | D | CS |
| Ferro alloys production | 1295 | 0.1 | 1227174 | 99.9 | Tier I | D | D |
| Aluminium production | 749 | 0.1 | 1227923 | 99.9 | Tier I | D | D |
| Carbide production | 302 | 0.0 | 1228225 | 100.0 | Tier I | D | D |
| Soda ash use | 273 | 0.0 | 1228498 | 100.0 | Tier I | D | D |
| Black carbon and styrene prod. | 42 | 0.0 | 1228540 | 100.0 | Tier I | D | D |

# Characteristic of Rice Cultivation in India

- Multiple Cropping System – both Rabi and Kharif season
- Variety of cultivars in use
- Cultivated all over India in upland, gangetic plains, and in the deccan plateau in the South
- Water management practices vary between arid, rainfed, irrigated, and deep water conditions
    - About 50% of area is irrigated
    - the rest is distributed between other water management practices

# INDIAN RICE PADDY HARVESTED AREA FROM 1979-1999



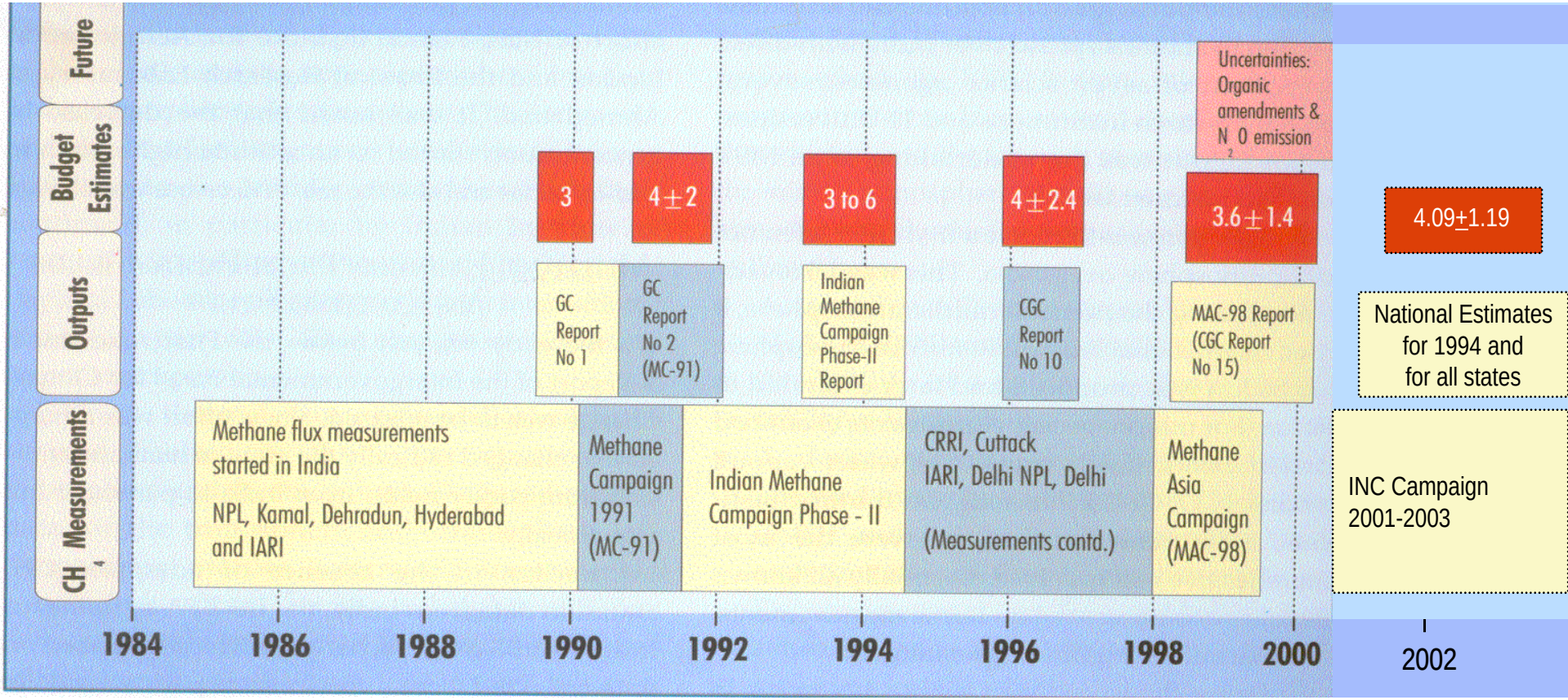
# Parameters affecting CH4 emission from rice cultivation

- Water management
- soil organic carbon content
- Soil Sulphate Content
- Soil Temperature
- Rice cultivar
- Fertilizer application

Methane emission rates vary markedly with water regimes

A single mid season drainage or multiple-aeration may reduce methane emission by about 50% without compromising on the rice yield

# Chronology of Measurements of Methane Efflux from Paddy Fields in India



# Methodology

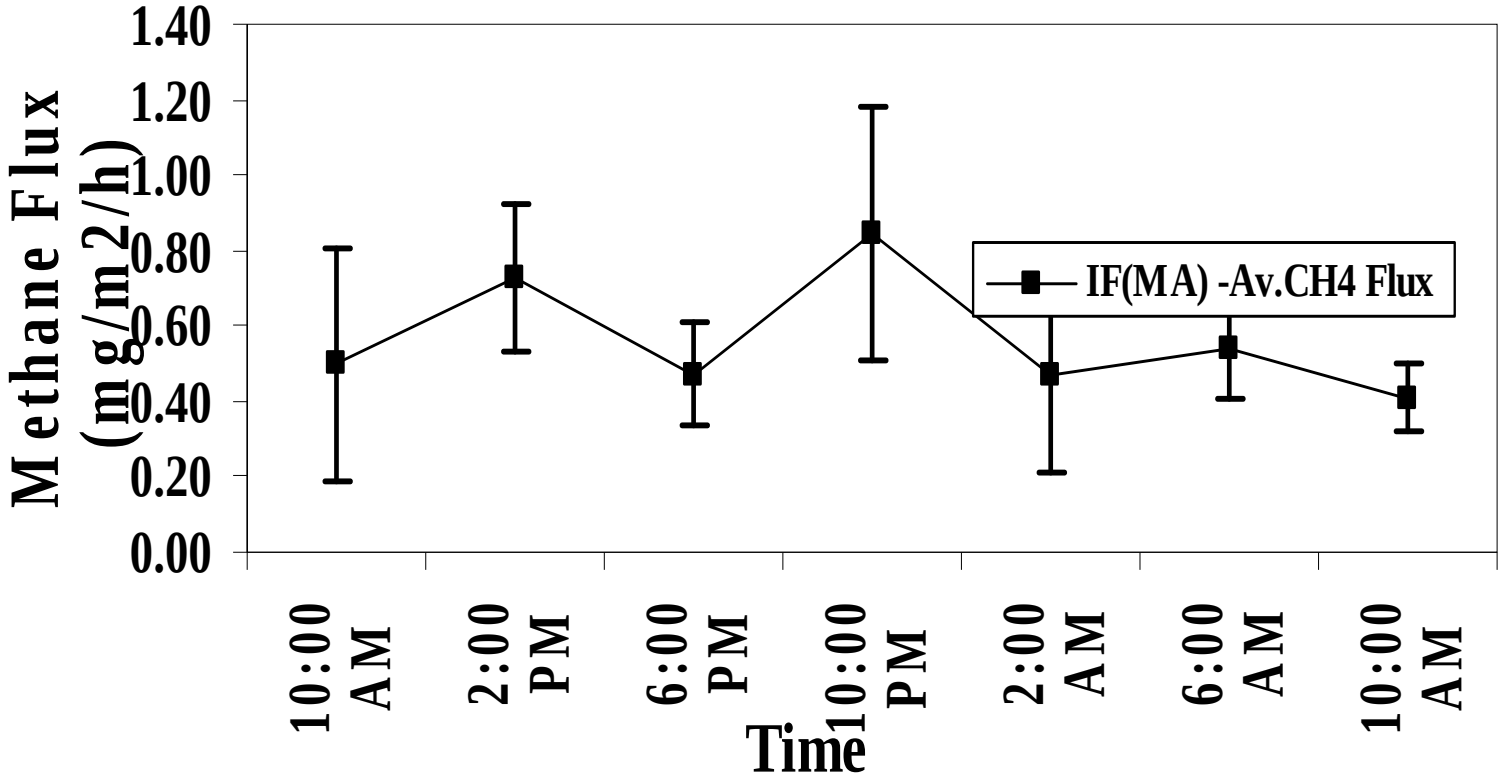

Static box or chamber technique

Flux measurements made in the forenoon and afternoon twice each week

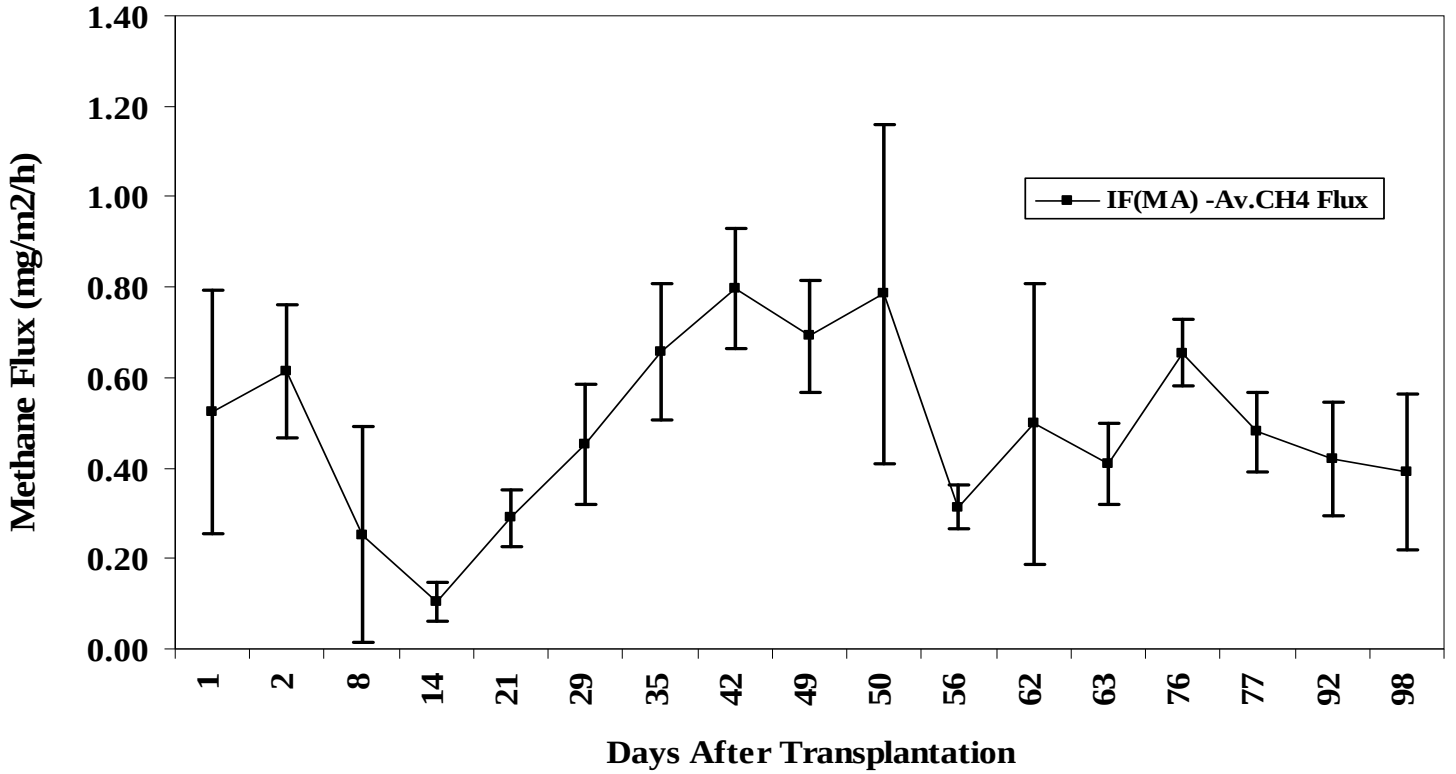
Samples at all sites collected manually in glass vials or syringes

- Automatic sampling systems also used at IRRI sites
- CH4 concentrations in samples determined using Gas chromatograph with flame ionisation detector (FID)
- NIST USA traceable methane calibration standards used
  Secondary standards calibrated nationally
  and internationally and inter-compared

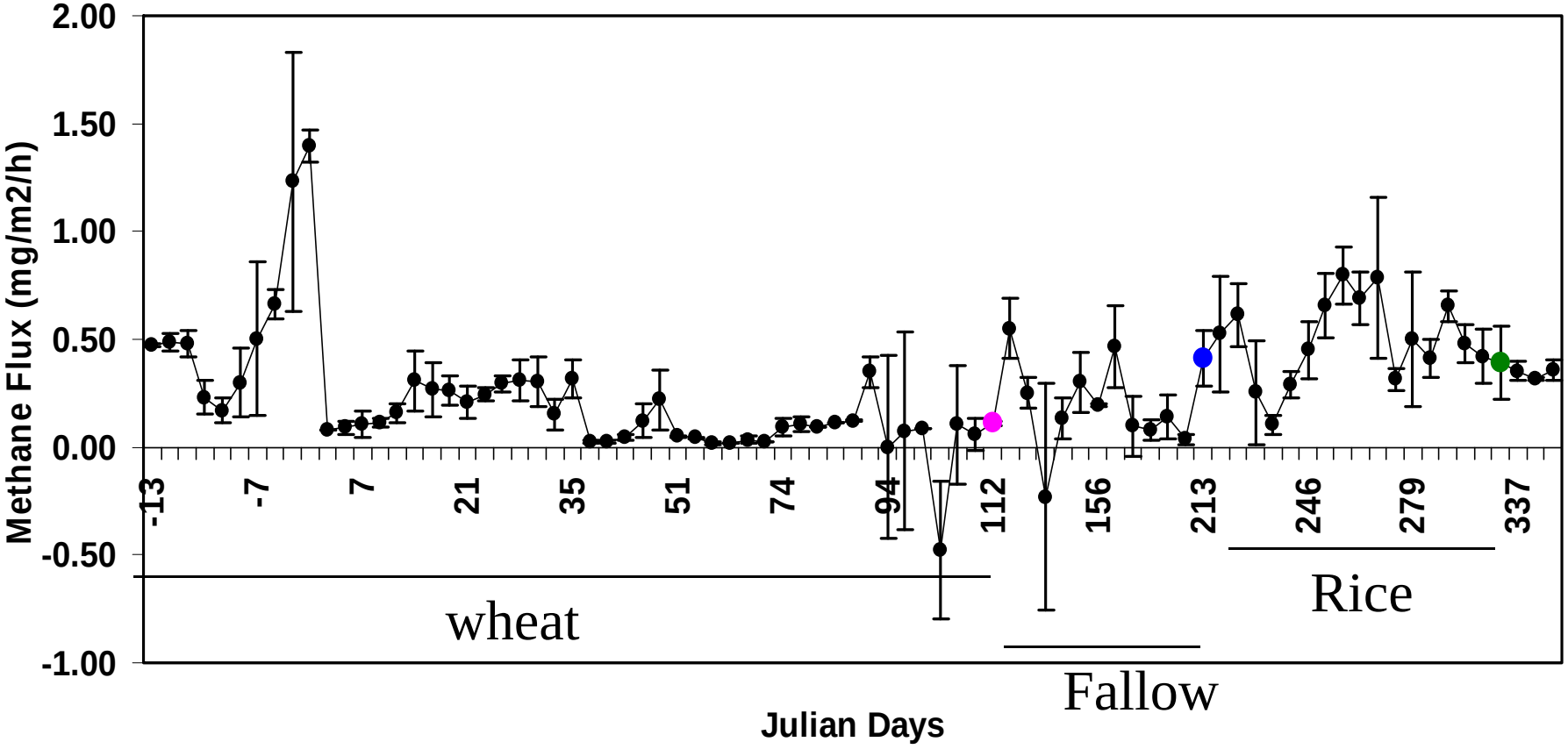
# Diurnal Methane flux Variations from Rice crop from Intermittently Flooded-MA fields for two days in October



# Seasonal Methane flux Variations from Rice crop in an Intermittently Flooded-MA for the period Aug to Nov



# Annual Methane Flux Variation
# Intermittently flooded- MA (Dec. 2001-Dec 2002)




**SIF(gm-2): 2.42 ± 0.92**

# Methane emission factors (*E*sif) for Indian paddy eco-systems (1991-2003)

| *Rice Eco-Systems* → Soil Organic Carbon/ Amendments ↓ | Rainfed *(flood prone)* | Rainfed *(drought prone)* | Continuously flooded | Intermittently flooded *(single aeration)* | Intermittently flooded *(multiple aeration)* | Deep water |
|---|---|---|---|---|---|---|
| Low Soil Org. C | 19.0±6.0 | 6.9±4.3 | 15.3±2.6 | 6.9±4.3 | 2.2±1.5 | 19.0±6.0 |
| Low Soil Org. C, with Org. Amend. | – | 12.5 | 12.0±4.0 | 12.5 | 4.8 | – |
| High Soil Org. C | – | 7.95±1.5 | 26.3±6.7 | 7.95±1.5 | 3.7±1.2 | – |
| High Soil Org. C, with Org. Amend. | – | – | 63±17 | – | – | – |
| Average $E_{sif}$ (g/m$^2$) (Range) | **19.0±6.0** | **9.12** (6.9 to 12.5) | **29.2** (12 to 63) | **9.12** (6.9 to 12.5) | **3.6** (2.2 to 4.8) | **19.0±6.0** |

Averaged for low & high organic carbon
paddy soils including with and without organic amendments

# Effect of water management/organic amendments on *E*sif

Methane emission ($E_{sif}$ g $m^{-2}$) during 1998 (Kharif or Wet season)

| | Pant Nagar, UP<br>Cultivar: Pant-4<br>NPK-60,50,40 kg/ha +<br>FYM @ 50%N | | | NPL New Delhi<br>Cultivar: P-169<br>Only FYM @10t/ha | | |
|---|---|---|---|---|---|---|
| | IF | CF(SA) | Factor | IF | CF | Factor |
| With organic amendment | 7.15 | 12.5 | **1.75** | 2.0 | 12.05 | **6.03** |
| Without organic amendments | 5.36 | 7.07 | **1.32** | – | – | – |
| Scaling factor | **1.33** | **1.77** | | – | – | – |

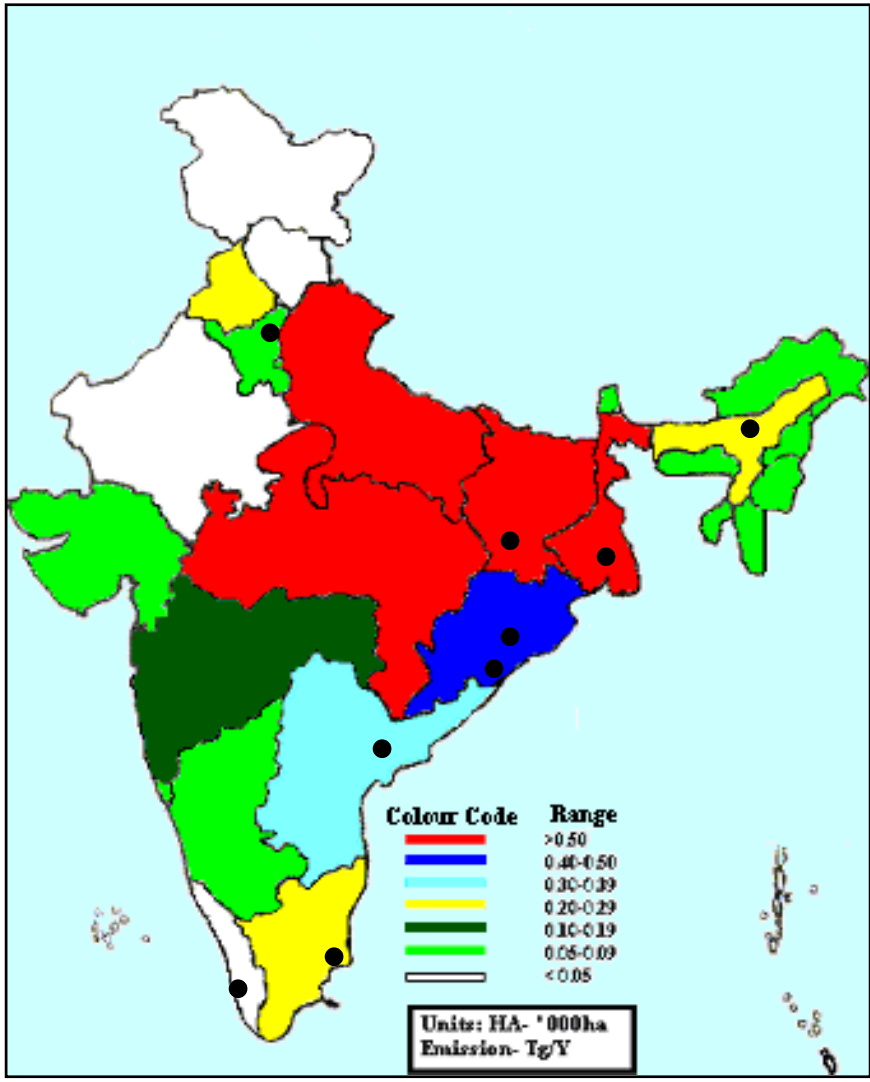
*Reference: Methane Asia Campaign, 1998*

# Institutional Arrangement (NATCOM)

MoEF

NPL

- NRSA. Hyderabad
- Anna Univ, Chennai
- PRL, Trivandrum
- IARI, New Delhi
- Assam Agri Univ, Jorhat
- CFRI, Dhanbad
- IRPE, Kolkata
- RRL, Bhbaneswar
- CRRI, Cuttak



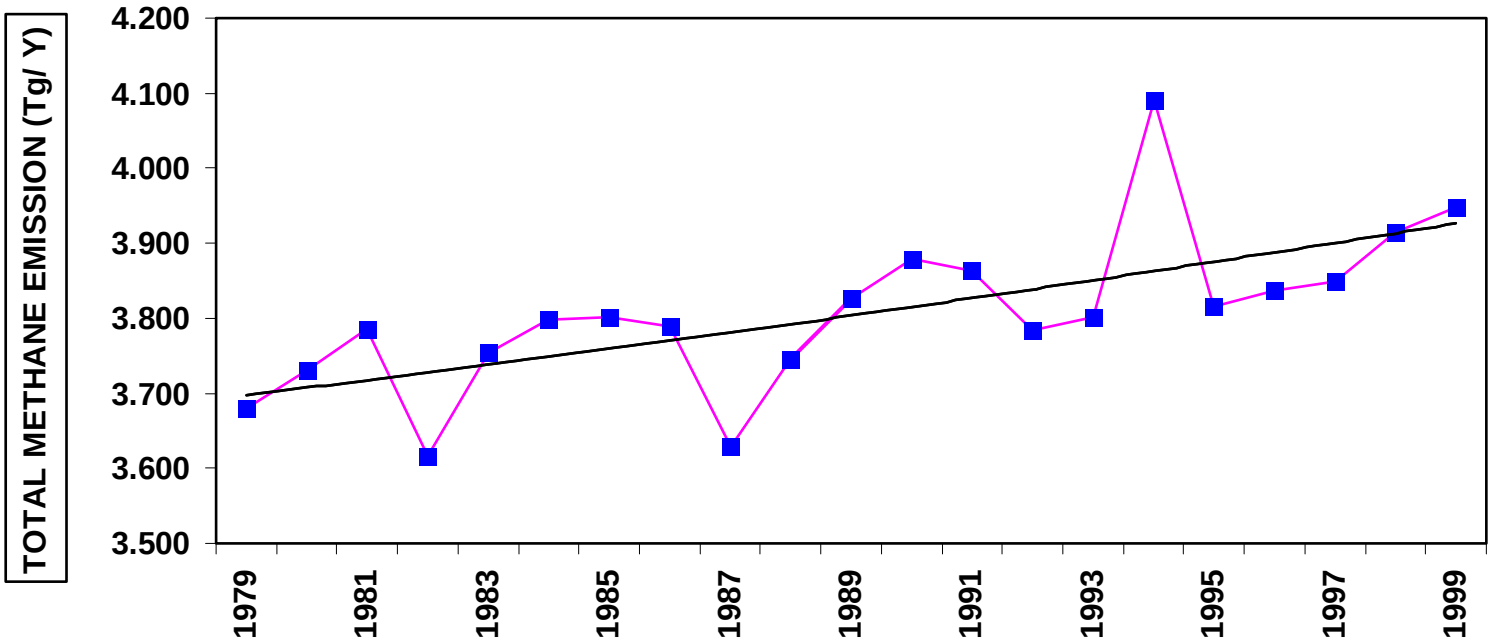
# Comparison of Emission Factors Across Different Studies

| Rice Ecosystem | Emission Factor (EF) in g $m^{-2}$ | | |
|---|---|---|---|
| | IPCC-96 | After MAC-98/ Earlier EFs | NATCOM Campaign Data Included |
| Upland | 0 | 0 | 0 |
| | | | |
| Rainfed Flood Prone | 16 | 19±6 | 19±6 |
| | | | |
| Rainfed, Drought Prone (RF-DP) | 8 | 6.9±4.3 | 6.95±1.86 |
| Irrigated, Continuously Flooded (IRR-CF) | 20 | 15.3±2.6 | 17.48±4.0 |
| Irrigated, Single Aeration (IRR-SA) | 10 | 6.9±4.3 | 6.62±1.89 |
| Irrigated Multiple Aeration (IRR-MA) | 4 | 2.2±1.5 | 2.01±1.49 |
| Deep Water | 16 | 19±6 | 19±6 |

# Distribution of Area Under Different Water Management Regime

| Water regime | | | | Percentage of area | Area (mha) |
|---|---|---|---|---|---|
| UPLAND | | | | 15 | 6.35 |
| LOWLAND | Rain-fed | Flood prone | | 10 | 4.23 |
| | | Drought prone | | 16 | 6.77 |
| | Irrigated | Continuously flooded | | 16 | 6.77 |
| | | Intermittently flooded | Single aeration | 23.5 | 9.92 |
| | | | Multiple Aeration | 13.5 | 5.74 |
| | Deep water | Water depth 50-100 cm | | 6 | 2.54 |
| | | Water depth >100 cm | | - | - |

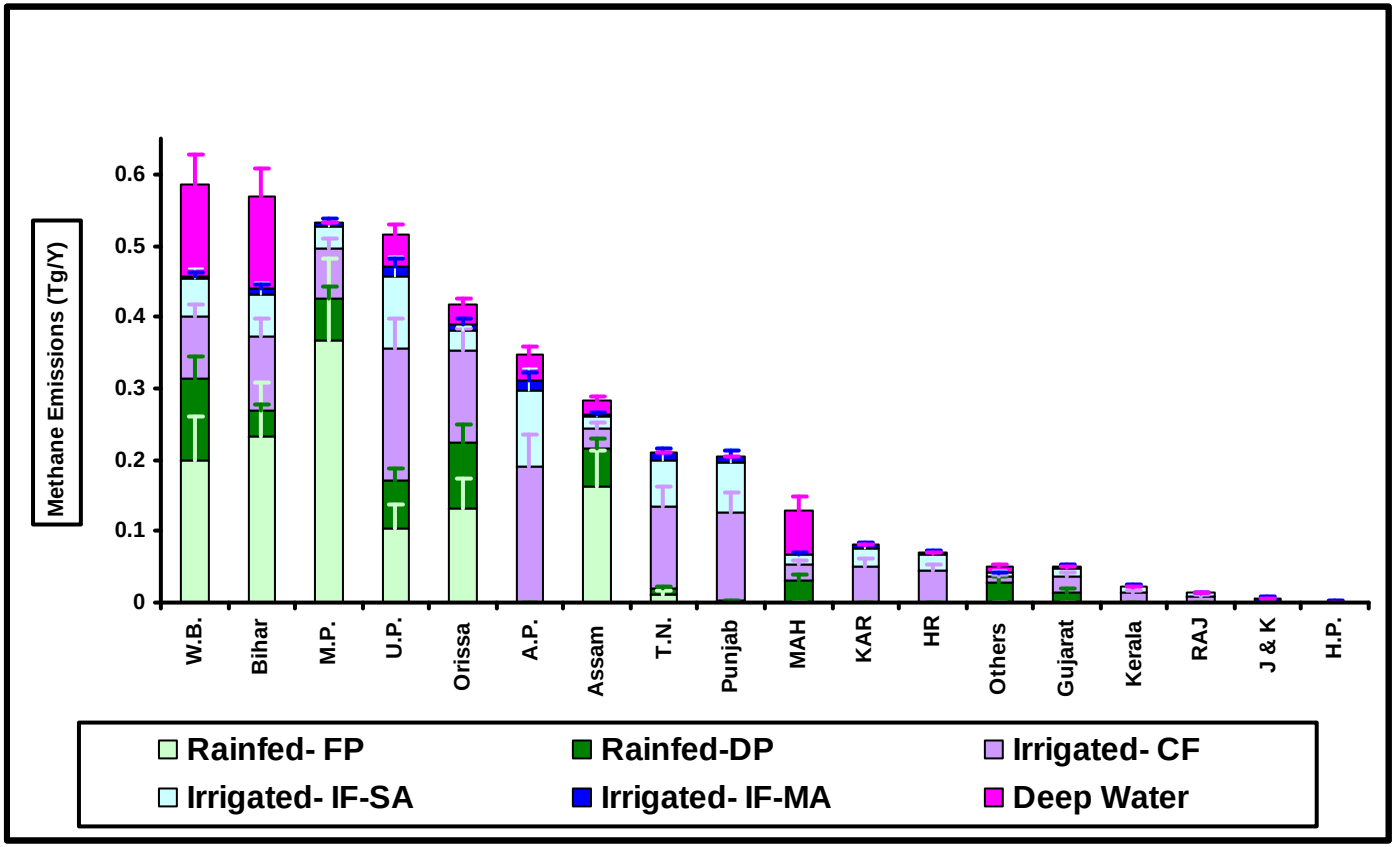
# Trends of CH4 Emission Across two Decades



# State Wise distribution of CH4 Emission from rice Paddy Field

| STATES | CH4 Emission (Tg/Y) |
|---|---|
| W.B. | 0.59 ± 0.17 |
| Bihar | 0.57± 0.17 |
| M.P. | 0.53± 0.16 |
| U.P. | 0.52± 0.15 |
| Orissa | 0.42± 0.12 |
| A.P. | 0.35± 0.10 |
| Assam | 0.28± 0.08 |
| T.N. | 0.21± 0.06 |
| Punjab | 0.20± 0.06 |
| Maharashtra | 0.13± 0.04 |
| Karnataka | 0.08± 0.02 |
| Haryana | 0.07± 0.02 |
| Others | 0.05± 0.01 |
| Gujarat | 0.05± 0.01 |
| Kerala | 0.02± 0.01 |
| Rajasthan | 0.01± 0.00 |
| J & K | 0.00± 0.00 |
| H.P. | 0.00± 0.00 |
| Total | 4.09± 1.19 |

# Cumulative State Wise CH4 emission Distribution from different states in India



# Achievements

| Pre -1995 | Post 1995 |
|---|---|
| Estimates restricted to irrigated, rainfed, upland | Estimates made for rainfed flood prone, rainfed drought prone; irrigated continuously flooded, irrigated single aeration, aerated multiple aeration; deep water & upland |
| Sporadic diurnal measurements in the cropping period | Seasonal ( 1995 onwards) and Annual (beyond 1998) |
| Restricted to North and western part of India | Campaign spread to the rice major growing regions including the South, East and the North East parts of India |

# Achievements – Post 1995

- CH4 Emission factors also assessed for soils with high organic content
- Estimates of CH4 brought down from 37.6 Mt to around 4 Mt
- Strong element of quality control and quality control in the measurements
- Level of uncertainties associated with the estimates of CH4 from rice cultivation determined
- Areas where single aeration and multiple aeration practices can replace the practice of continuously flooding the fields

# Uncertainties and Research Questions

- Annual variations in rice area under various water management practices
- High level of uncertainties introduced due to lack of data in certain hotspots like Madhya Pradesh

Thank you