# Climate Change and Greenhouse Gas Emissions


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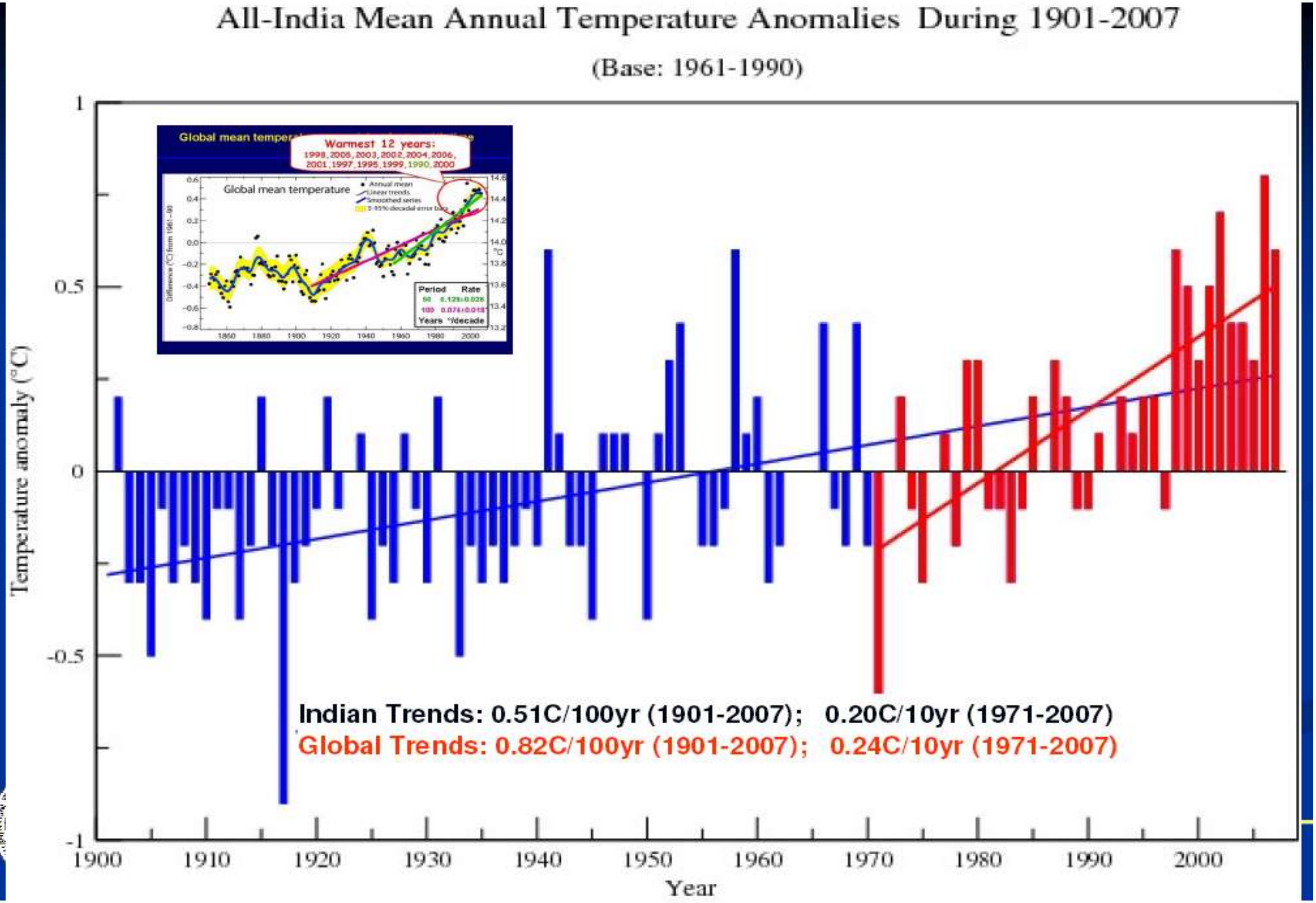
# Layout of presentation

- Background
- GHG Emission Inventories
- Efforts for Reduction of Uncertainties
- Emission Inventories and Climate Change Modeling

# Direct Observations of Global warming

**Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.**

**IPCC AR4**



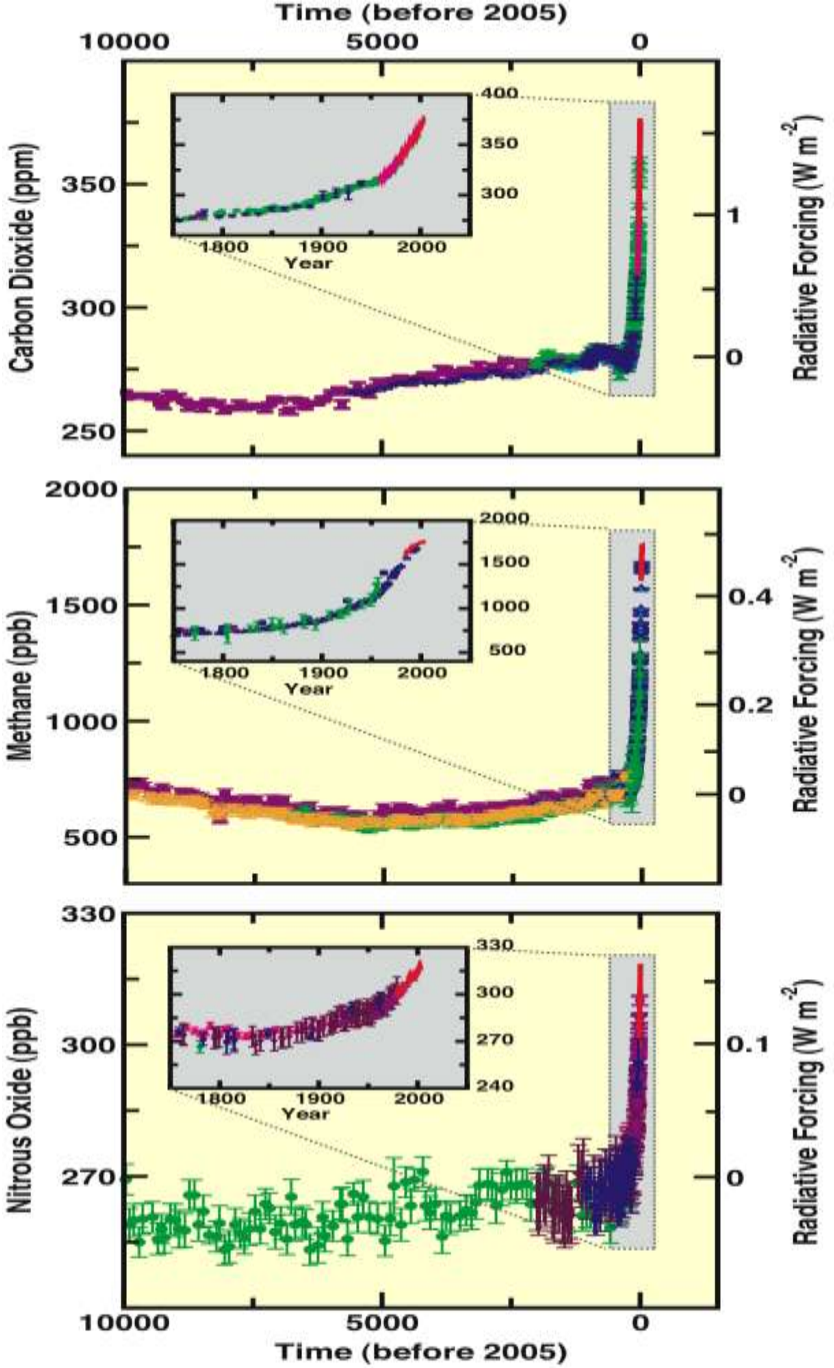

Source: Krishna Kumar, NATCOM 2009

# Human and Natural Drivers of Climate Change

$CO_2$, $CH_4$ and $N_2O$ Concentrations

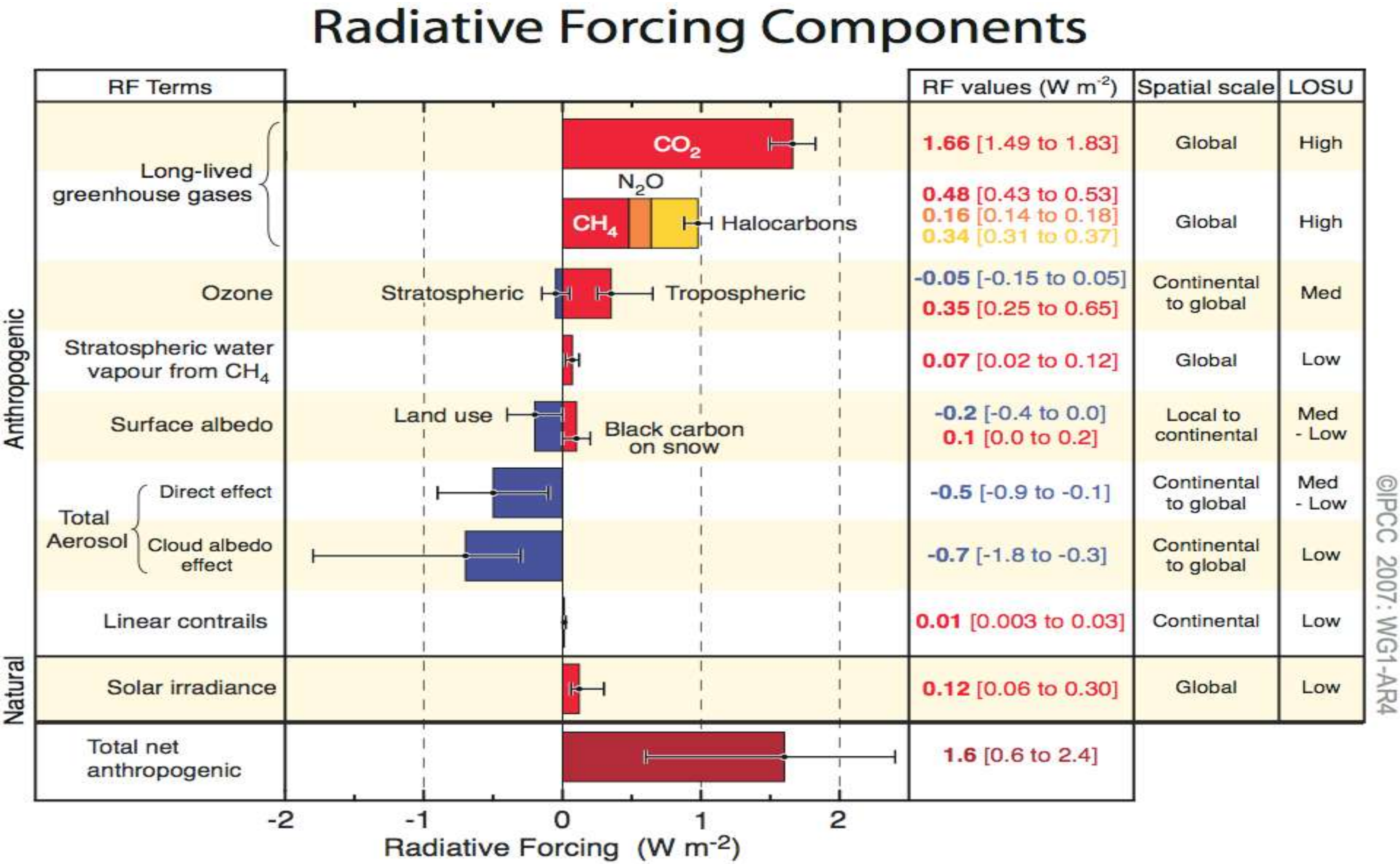
- far exceed pre-industrial values
- increased markedly since 1750 due to human activities

Relatively little variation before the industrial era




IPCC AR4

# Global-average radiative forcing estimates and ranges



# Climate Change Assessments in Retrospect

## Global

- Emergence of climate change as an issue, 1988
- United Nations Framework Convention on Climate Change, 1992
- IPCC Assessments
  - Science
  - Impacts, Vulnerability & Adaptation
  - Mitigation

  (1992, 1997, 2002, 2007)

## India

- ADB study, 1994 & 1998

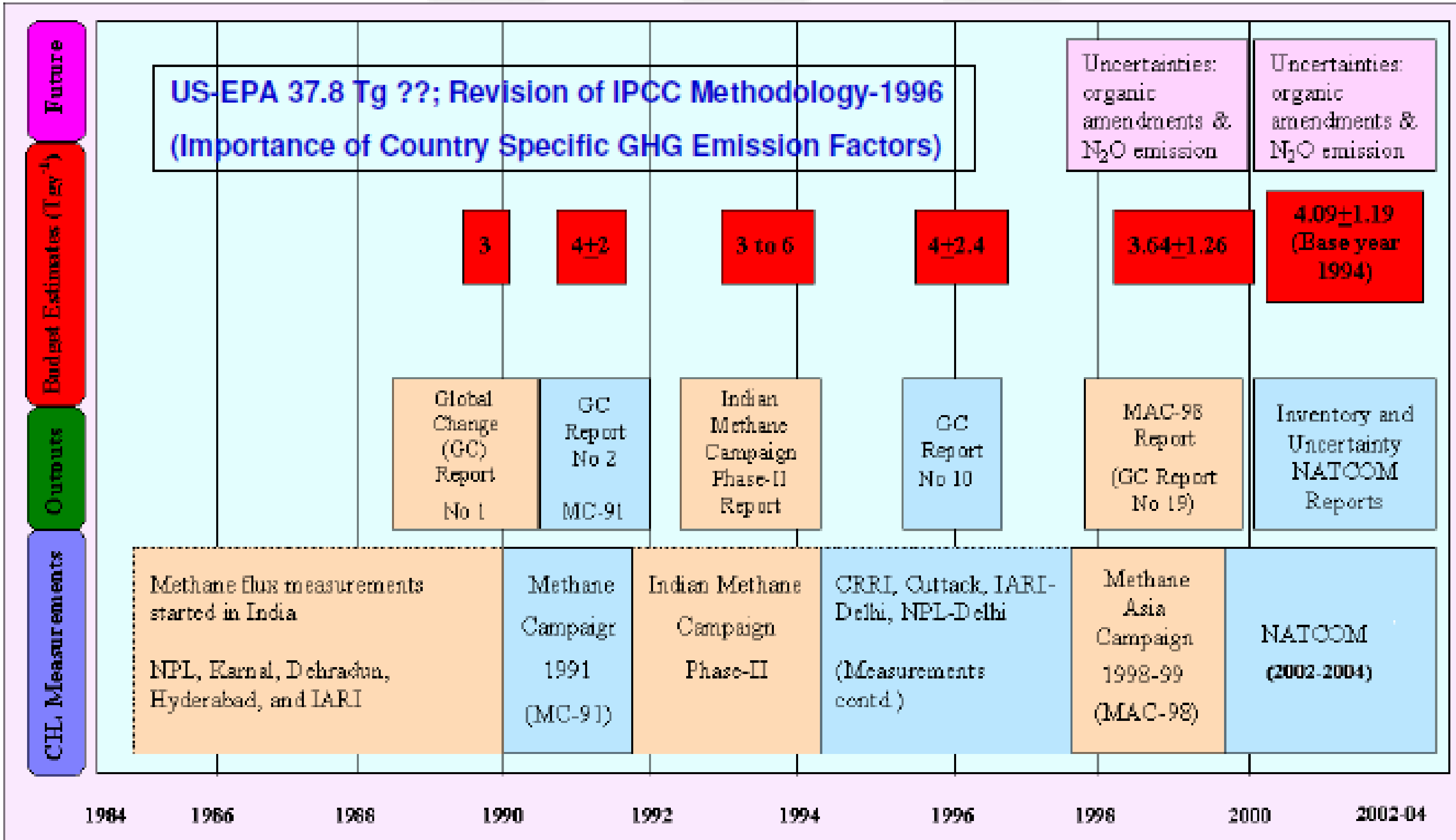
  Focus- Impacts of Climate variability & Observed Climate on agriculture & sea level rise, GHG inventory 1990 & Project based assessments of Mitigation potential
- NATCOM I, 2004

  Focus – Climate change scenarios, CC impacts at sectoral levels, GHG inventory for base year 1994 & development of country specific EFs
- Other isolated studies by researchers

Source: S. K. Sharma, NATCOM 2009

## *Greenhouse Gas Emission Inventories*

# Data Quality and International Traceability through NMI - $CH_4$ from Rice example



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

INCCA 2007

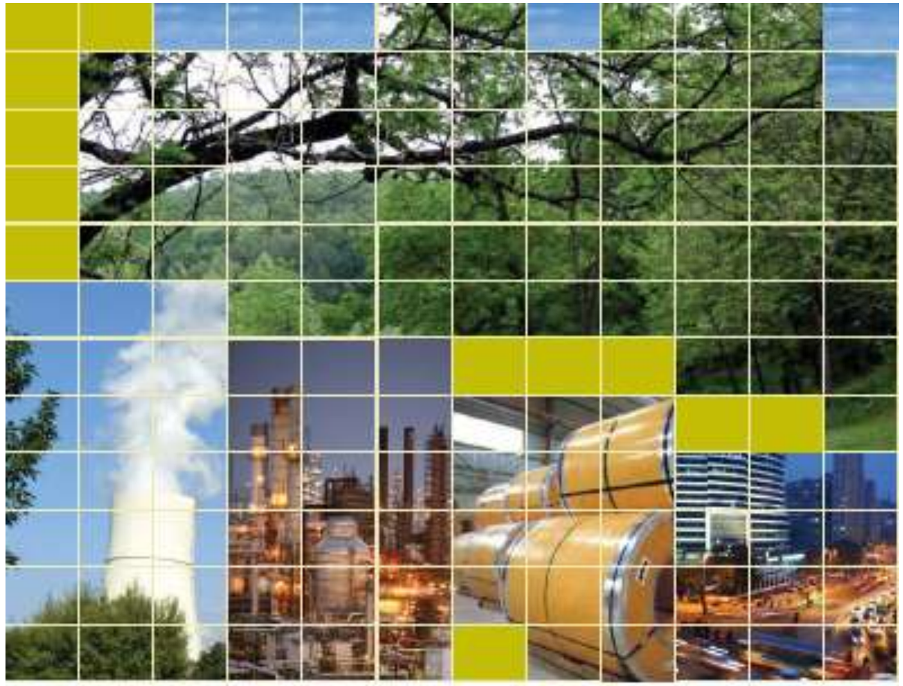
2010

# Initial National greenhouse gas inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol – NATCOM I

| 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** | **743810** |
| ***Fuel combustion*** | | | | | |
| Energy and transformation industries | 353518 | | | 4.9 | 355037 |
| Industry | 149806 | | | 2.8 | 150674 |
| Transport | 79880 | | 9 | 0.7 | 80286 |
| Commercial/institutional | 20509 | | | 0.2 | 20571 |
| Residential | 43794 | | | 0.4 | 43918 |
| All other sectors | 31963 | | | 0.4 | 32087 |
| Biomass burnt for energy | | | 1636 | 2.0 | 34976 |
| ***Fugitive Fuel Emission*** | | | | | |
| Oil and natural gas system | | | 601 | | 12621 |
| Coal mining | | | 650 | | 13650 |
| **2. Industrial Processes** | **99878** | | **2** | **9** | **102710** |
| **3. Agriculture** | | | **14175** | **151** | **344485** |
| *Enteric Fermentation* | | | 8972 | | 188412 |
| *Manure Management* | | | 946 | 1 | 20176 |
| *Rice Cultivation* | | | 4090 | | 85890 |
| *Agricultural crop residue* | | | 167 | 4 | 4747 |
| *Emission from Soils* | | | | 146 | 45260 |
| **4. Land use, Land-use change and Forestry*** | **37675** | **23533** | **6.5** | **0.04** | **14292** |
| Changes in forest and other woody biomass stock | | 14252 | | | (14252) |
| Forest and grassland conversion | 17987 | | | | 17987 |
| Trace gases from biomass burning | | | 6.5 | 0.04 | 150 |
| Uptake from abandonment of managed lands | | 9281 | | | (9281) |
| Emissions and removals from soils | 19688 | | | | 19688 |
| **5. Other sources as appropriate and to the extent possible** | | | | | 0 |
| **5a. Waste** | | | **1003** | **7** | **23233** |
| Municipal solid waste disposal | | | 582 | | 12222 |
| Domestic waste water | | | 359 | | 7539 |
| Industrial waste water | | | 62 | | 1302 |
| Human sewage | | | | 7 | 2170 |
| **5b. Emissions from Bunker fuels #** | **3373** | | | | **3373** |
| Aviation | 2880 | | | | 2880 |
| Navigation | 493 | | | | 493 |

# Not counted in the national totals.

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



**INCCA** Indian Network for Climate Change Assessment

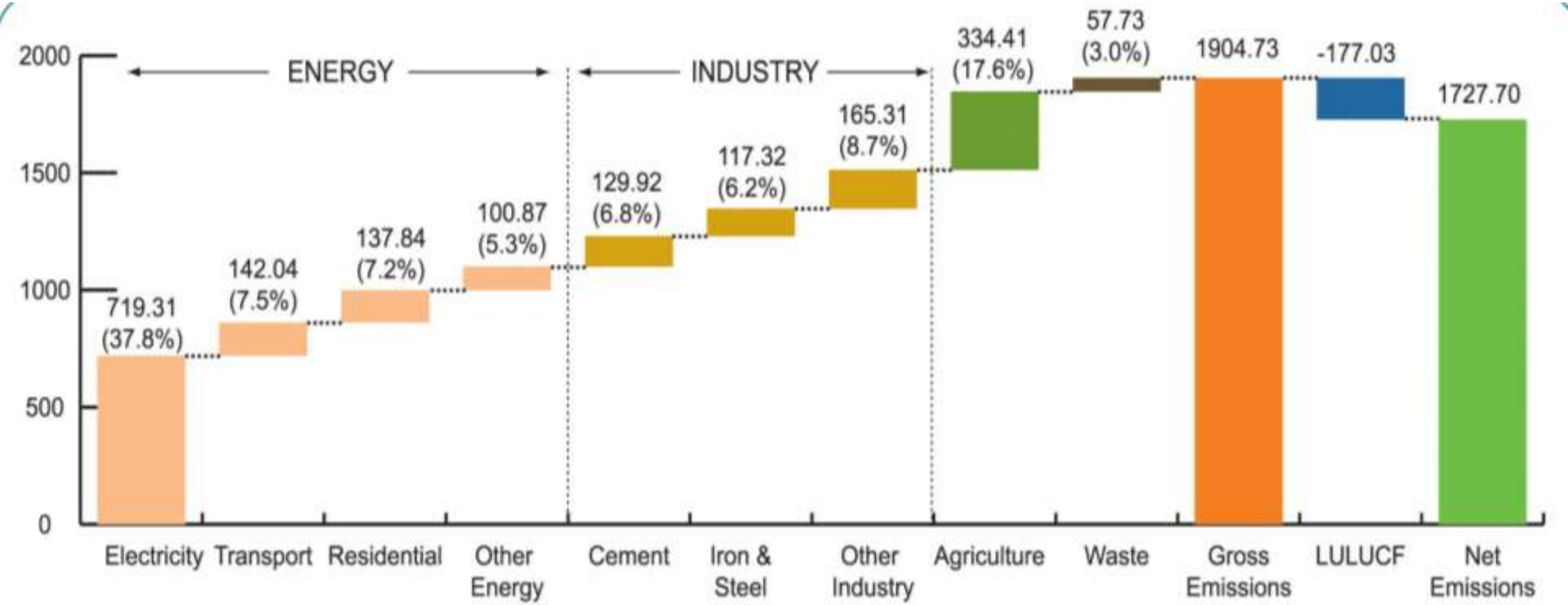
# India: Greenhouse Gas Emissions 2007

Ministry of Environment and Forests
Government of India

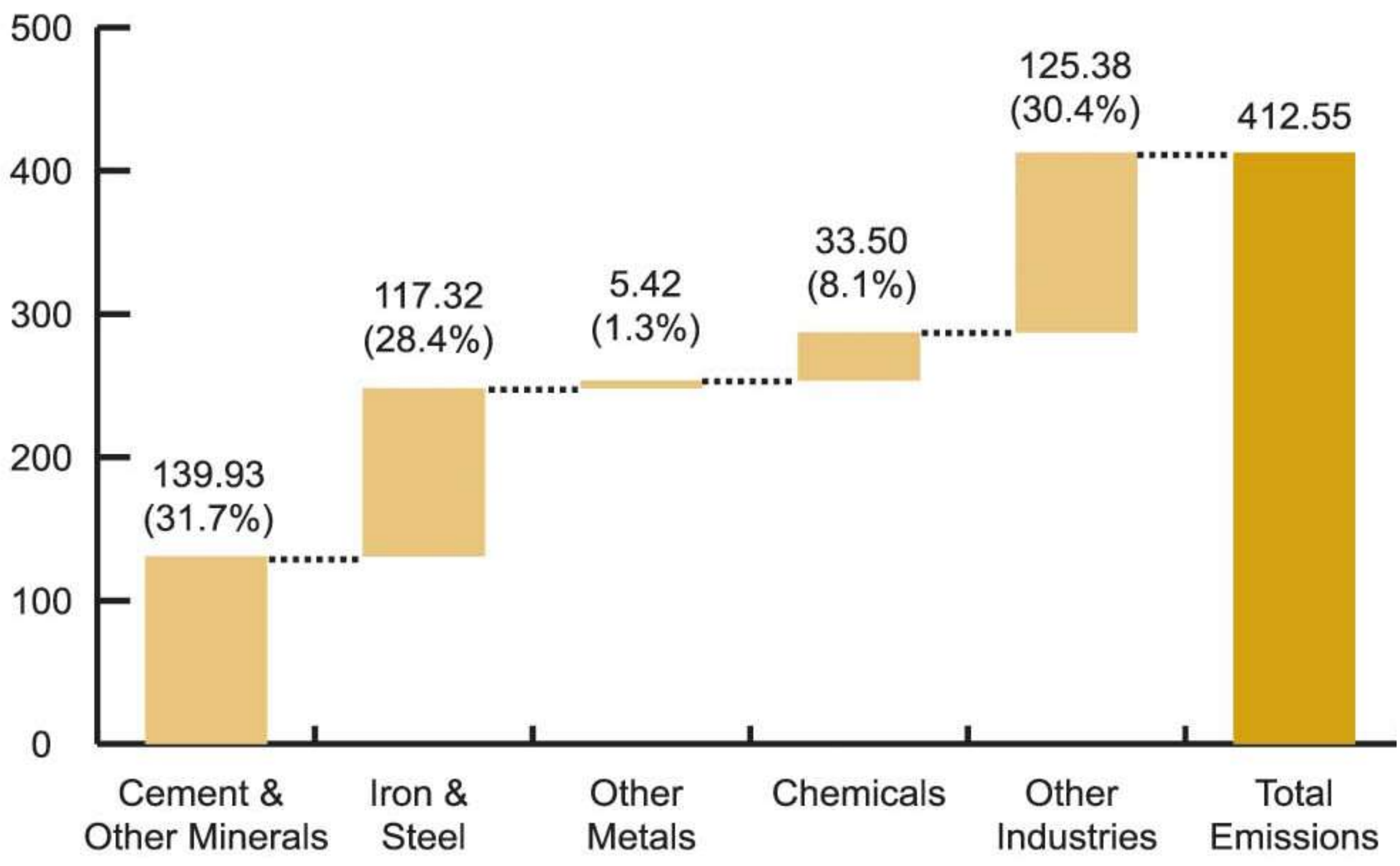
May 2010

http://www.moef.nic.in/

# GHG Emissions by Sector 2007 (million tons of $CO_2$ equivalent)

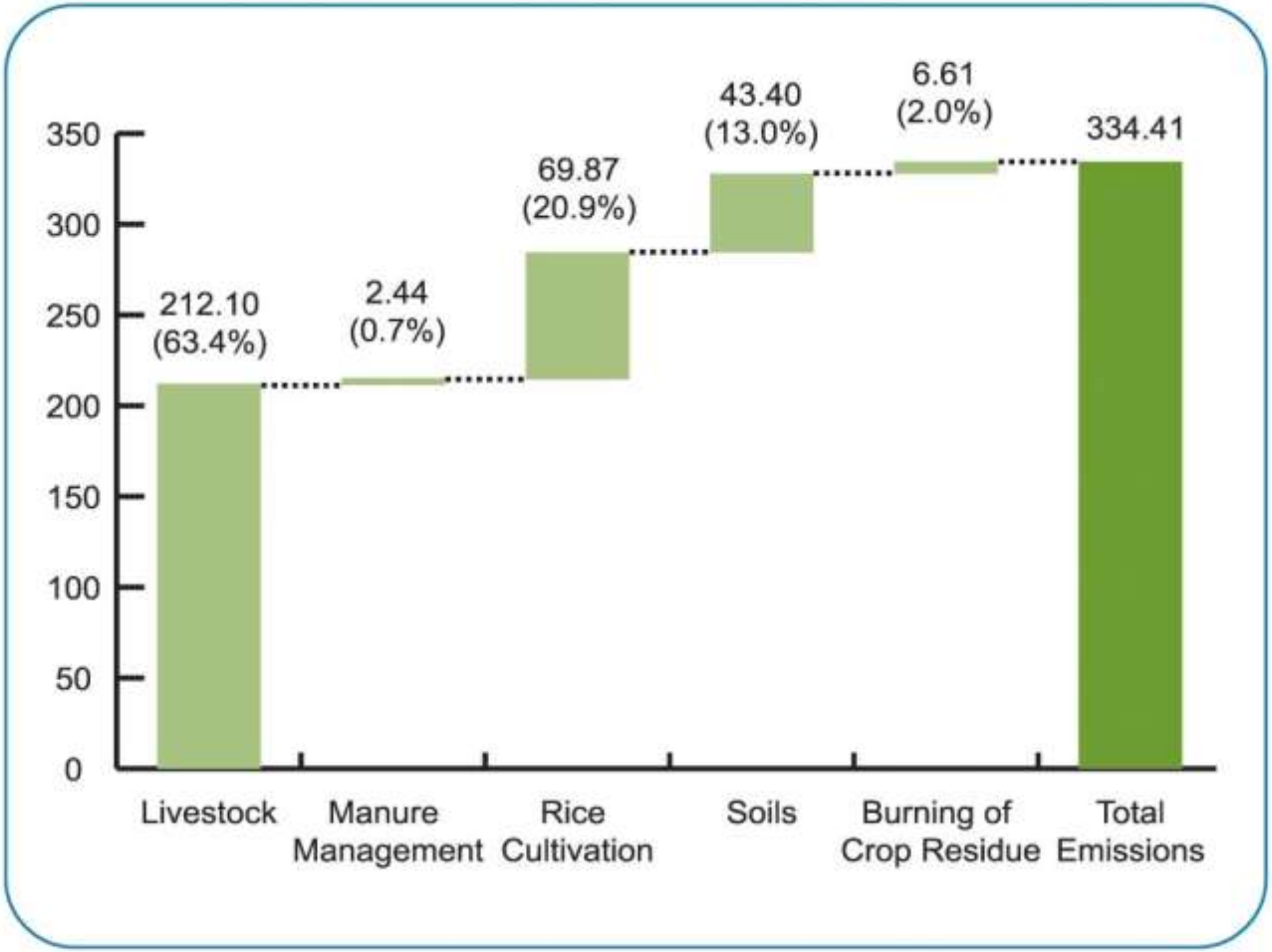


# GHG emissions from Industry (million tons of $CO_2$ equivalent)

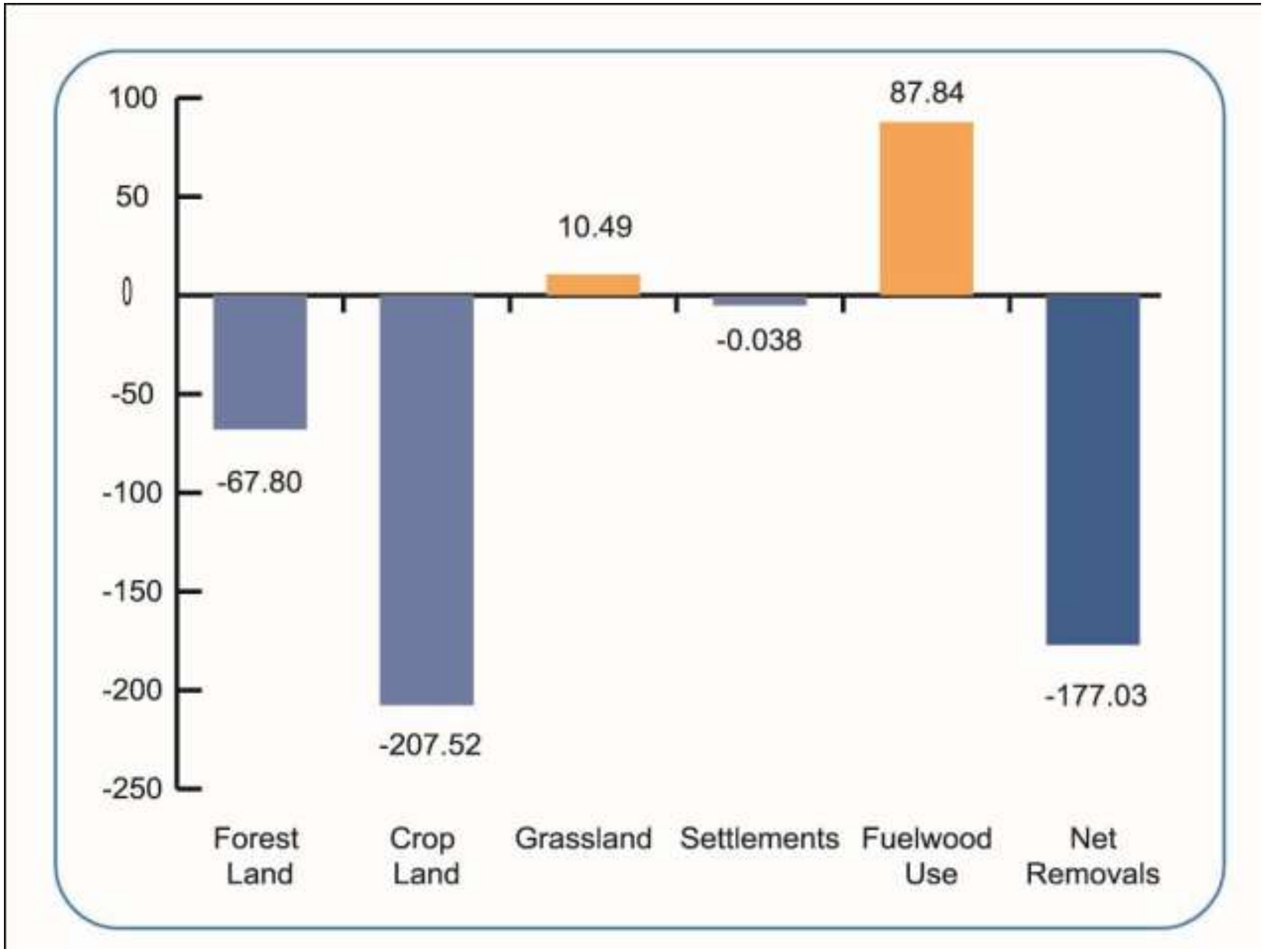


# GHG emissions from the Agriculture sector

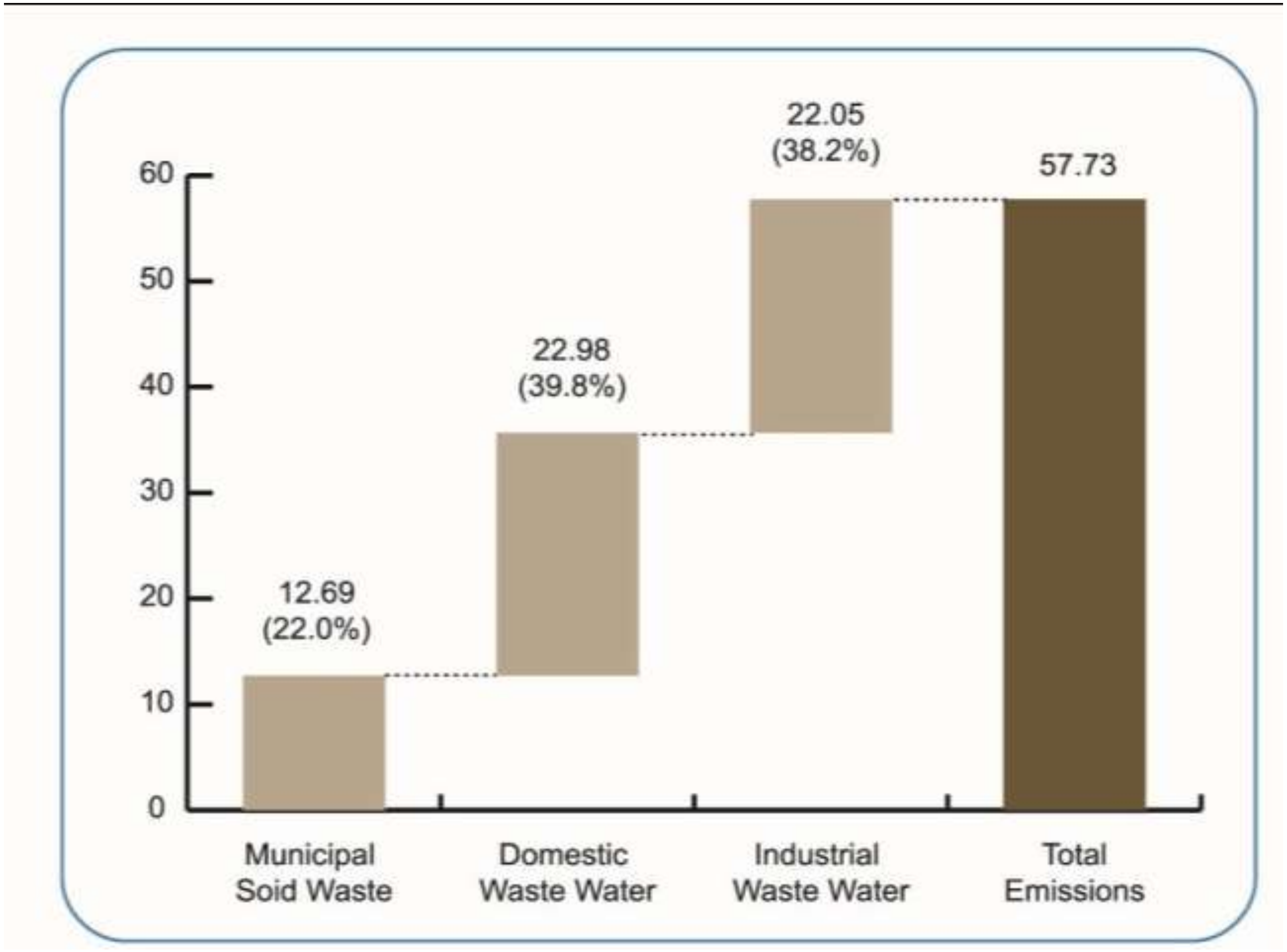
(million tons of $CO_2$ equivalent)



# GHG emissions from the LULUCF sector (million tons of $CO_2$ eq.)



# GHG emissions from Waste sector (million tons of $CO_2$ equivalent)



# Key Results

- The total net Greenhouse Gas (GHG) emissions from India in 2007 were 1727.71 million tons of $CO_2$ equivalent (eq) of which
  - $CO_2$ emissions were 1221.76 million tons;
  - $CH_4$ emissions were 20.56 million tons; and
  - $N_2O$ emissions were 0.57 million tons

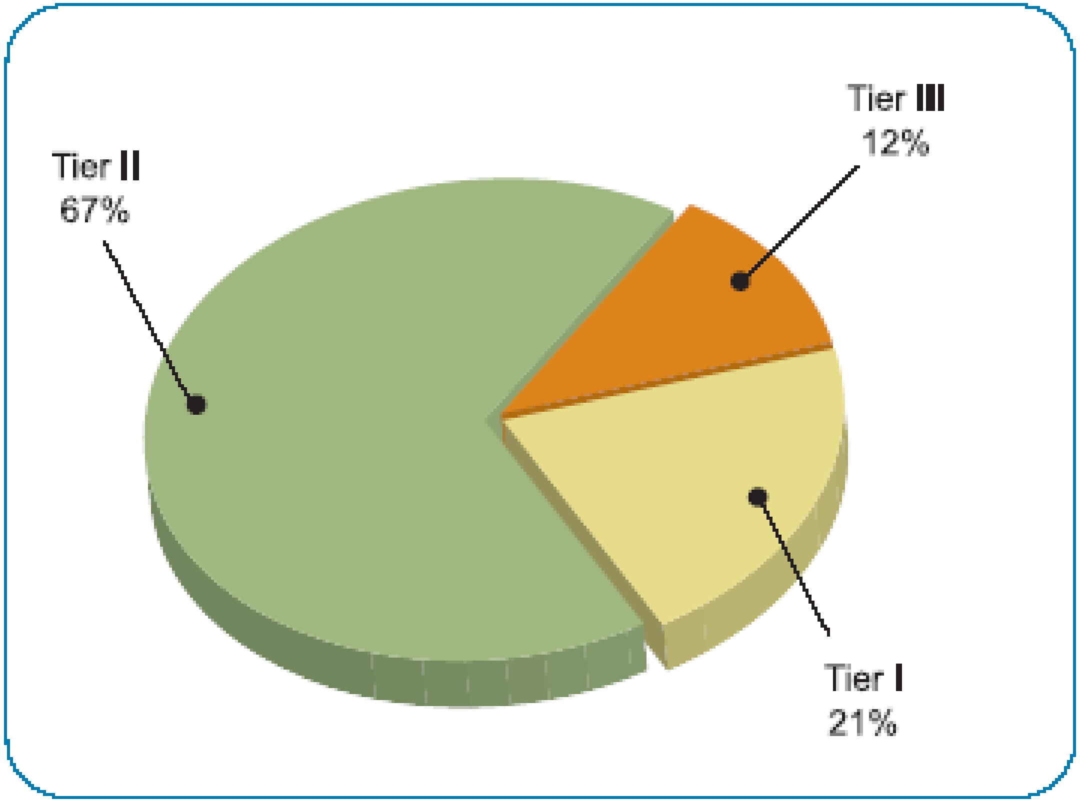
- GHG emissions from Energy, Industry, Agriculture, and Waste sectors constituted 58%, 22%, 17% and 3% of the net $CO_2$ eq emissions respectively.

- Energy sector emitted 1100.06 million tons of $CO_2$ eq, of which 719.31 million tons of $CO_2$ eq were emitted from electricity generation and 142.04 million tons of $CO_2$ eq from the transport sector.

- Industry sector emitted 412.55 million tons of $CO_2$ eq. LULUCF sector was a net sink. It sequestered 177.03 million tons of $CO_2$.

- India's per capita $CO_2$ eq emissions including LULUCF were 1.5 tons/capita in 2007.

# Tiers of methodology used for 2007 GHG emission profile




**Tier I : approach employs activity data that are relatively coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps.**

**Tier 2 use the same methodological approach as Tier 1 but applies emission factors and activity data which are defined by the country.**

**Tier 3 approach uses higher order methods are used including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by disaggregated levels.**

# *Efforts for reduction of uncertainties in emission inventories - Examples*

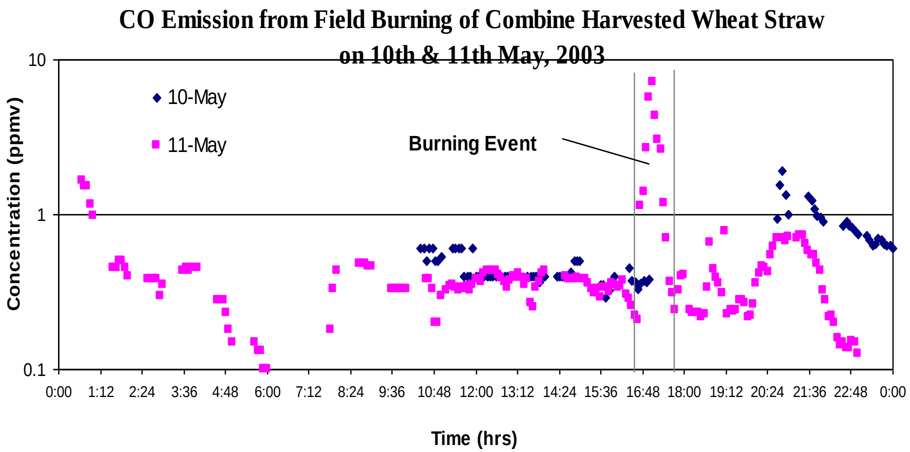
# Assessment of trace gases, carbon and nitrogen emissions from field burning of agricultural residues in India

*Sahai et. al., Nutrient Cycling in Ago-ecosystem, (In press - 2010)*

# Agricultural Residue Burning in the Farms of G B Pant University of Agriculture & Technology (Pantnagar)

## Wheat Straw Burning May 2003

## Rice Straw Burning November 2003



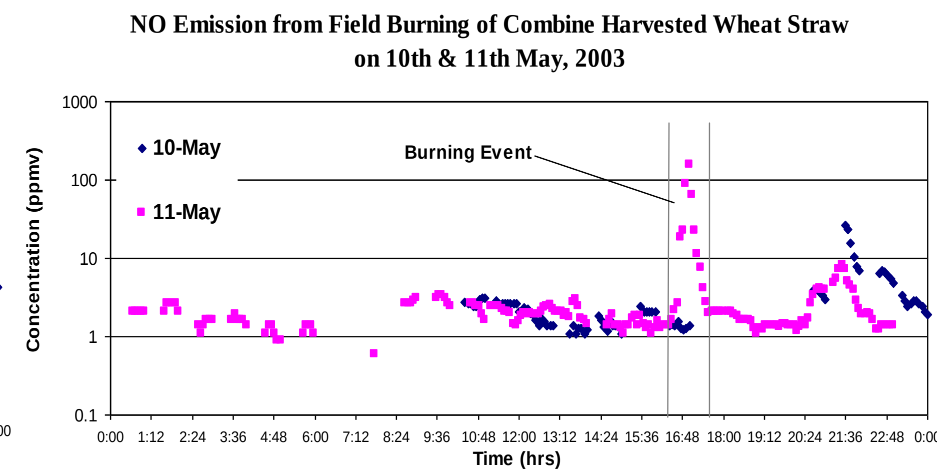
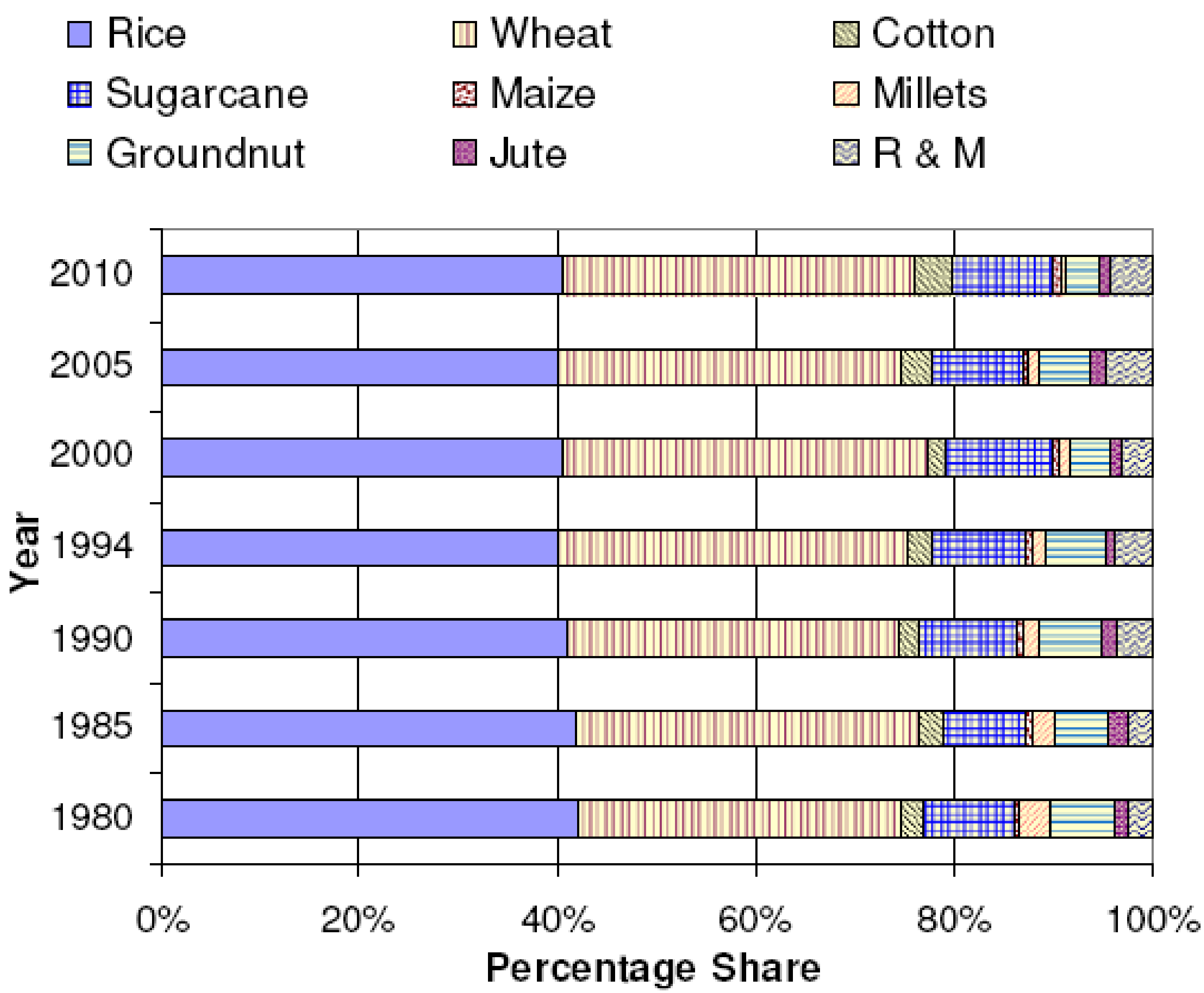
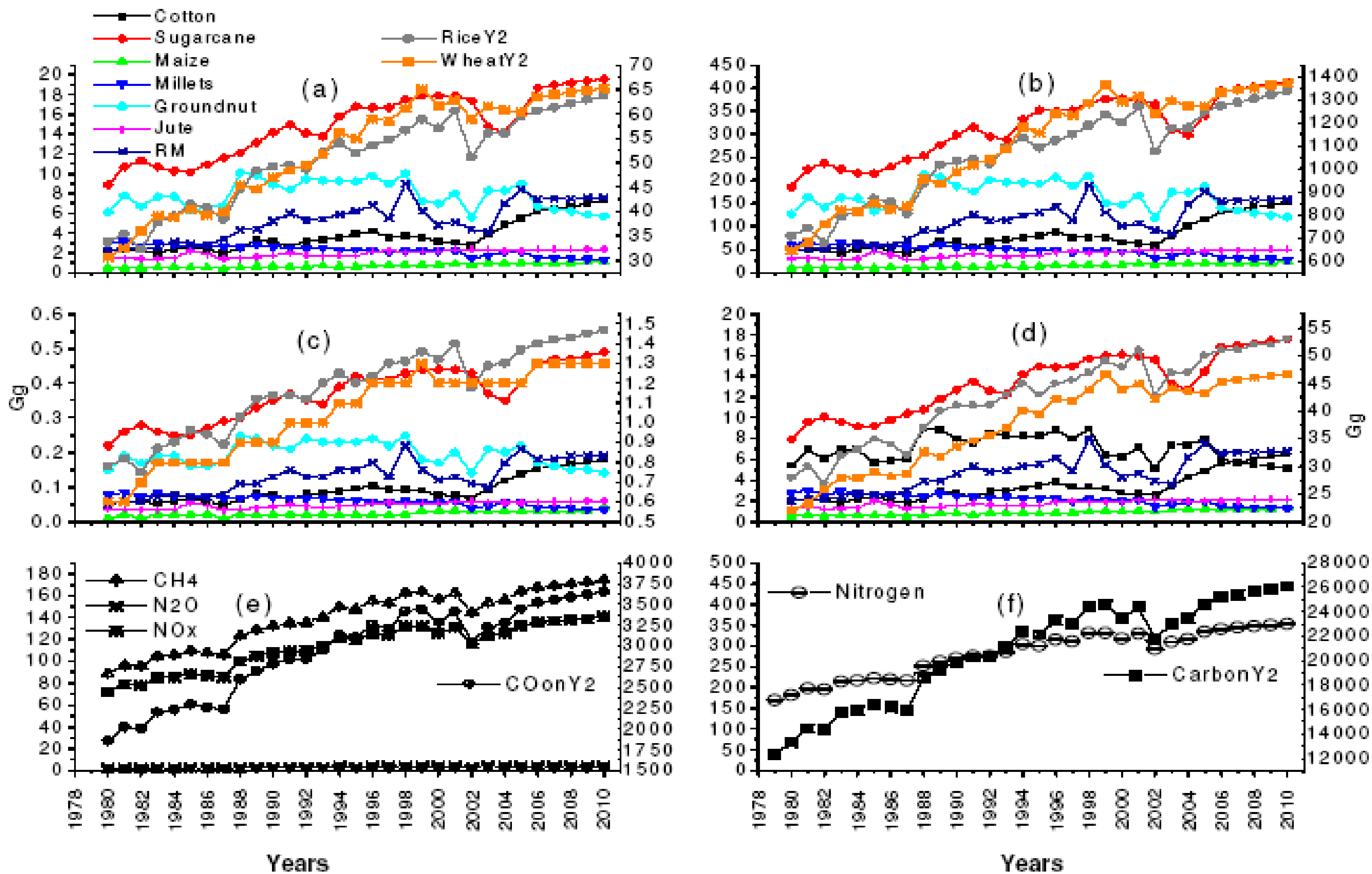



**Figure 1: Shares of different crops in dry residue generation**



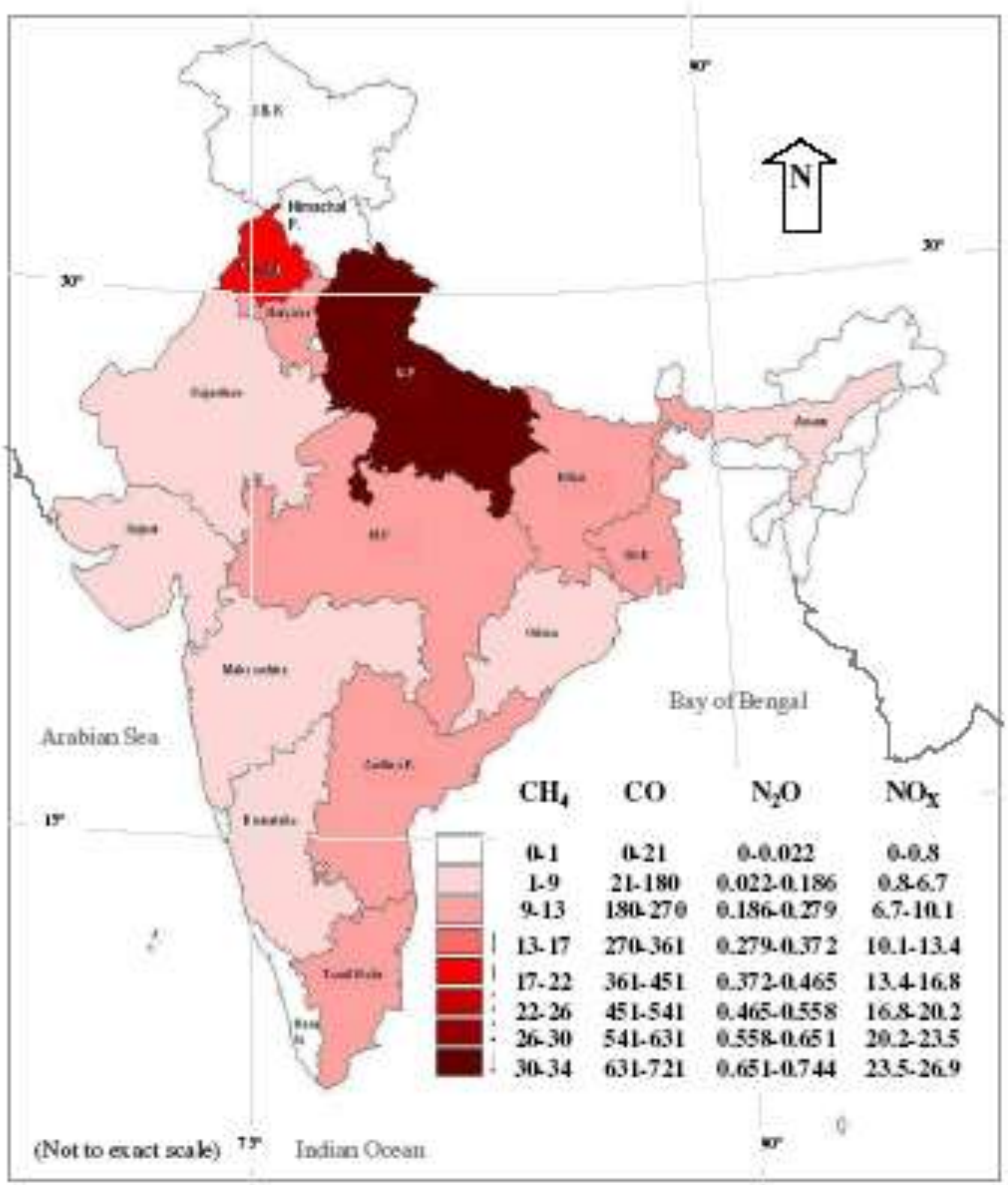

*Sahai et al. 2010*

**Figure 2: Crop-wise emission variation of (a) $CH_4$, (b) CO, (c) $N_2O$, (d) $NO_X$ (a, b, c & d have same legends and emissions fo rice and wheat are shown on Y2 axis); (e) trace gases emission from total of all crops; and (f) total nitrogen and carbon fro all crops, between 1980 and 2010 from FBCR (Gg)**




*Sahai et al. 2010*

**Figure 4: State-wise emission distribution of $CH_4$, CO, $N_2O$ and $NO_X$ from FBCR in India for the year 1994 (in Gg)**




| $CH_4$ | CO | $N_2O$ | $NO_X$ |
|---|---|---|---|
| 0-1 | 0-21 | 0-0.022 | 0-0.8 |
| 1-9 | 21-180 | 0.022-0.186 | 0.8-6.7 |
| 9-13 | 180-270 | 0.186-0.279 | 6.7-10.1 |
| 13-17 | 270-361 | 0.279-0.372 | 10.1-13.4 |
| 17-22 | 361-451 | 0.372-0.465 | 13.4-16.8 |
| 22-26 | 451-541 | 0.465-0.558 | 16.8-20.2 |
| 26-30 | 541-631 | 0.558-0.651 | 20.2-23.5 |
| 30-34 | 631-721 | 0.651-0.744 | 23.5-26.9 |

*Sahai et al. 2010*

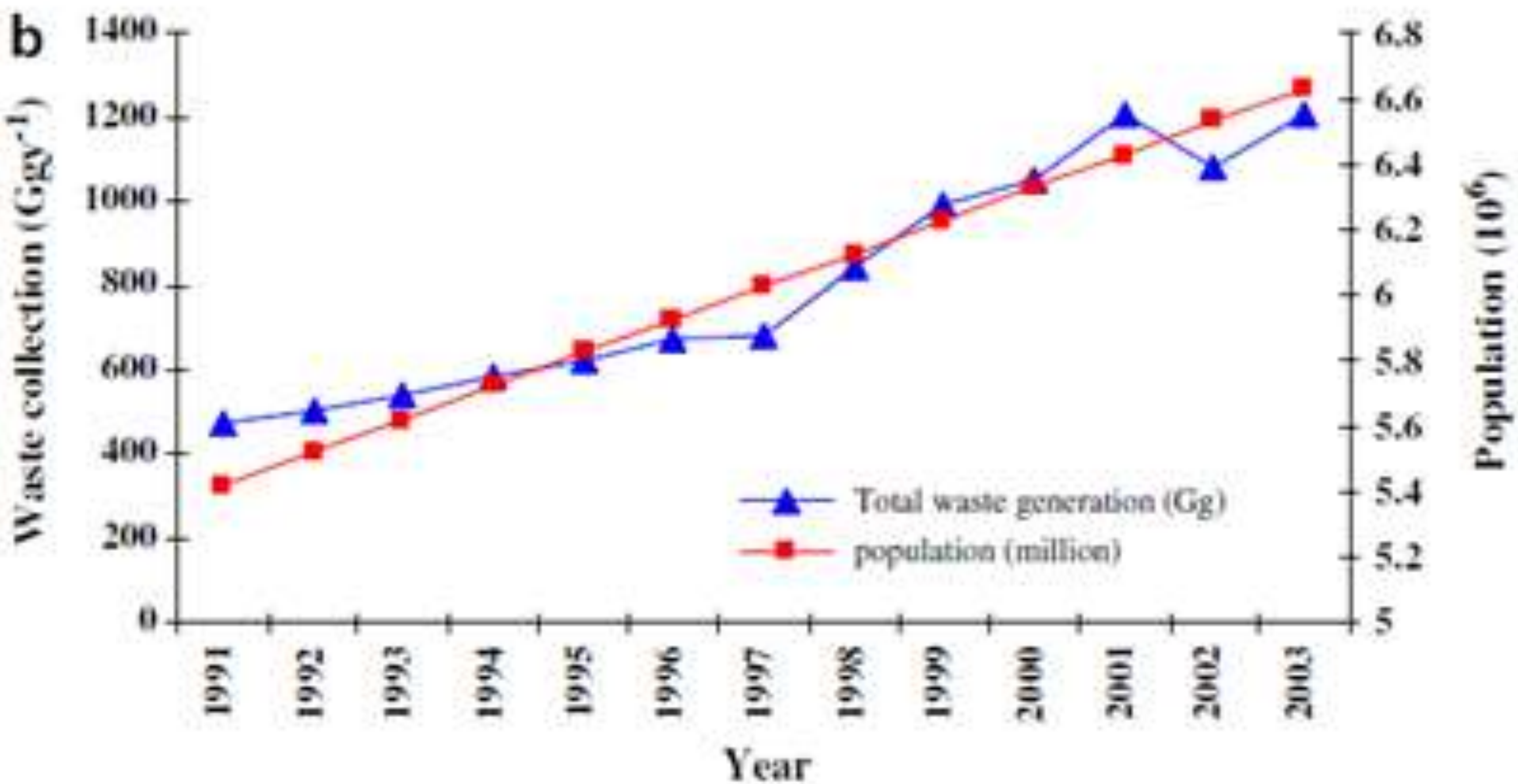
# Greenhouse gas Emissions from landfills

# Scenario of municipal solid waste in four mega cities

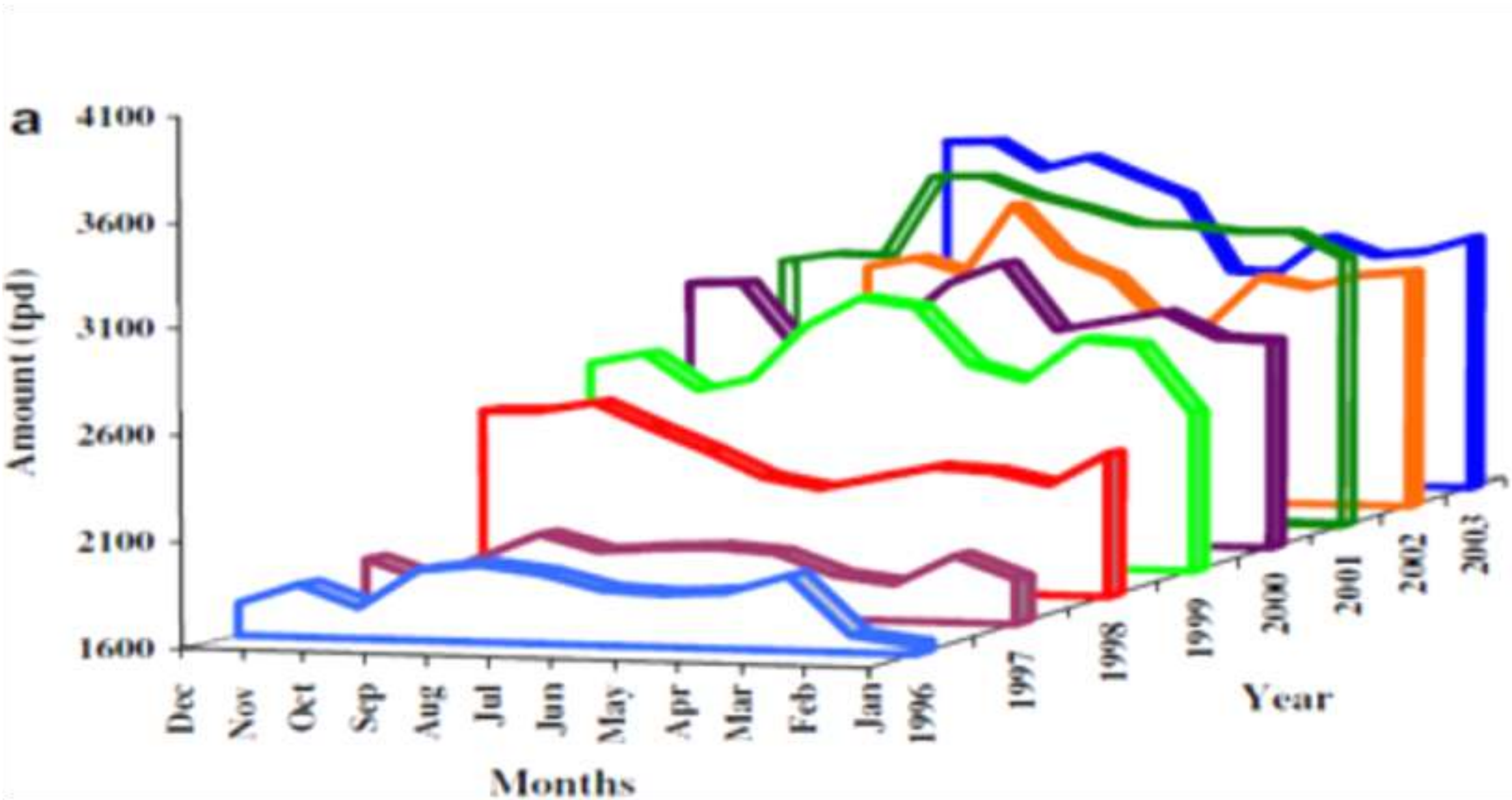
| Parameter | Year | Mega-cities | | | |
|---|---|---|---|---|---|
| | | Chennai | Delhi | Kolkata | Mumbai |
| Area (km2) | | 174.0 | 148.4 | 187.33 | 437.71 |
| Population (million) | 1981 | 4.28 | 6.22 | 4.13 | 8.23 |
| | 1991 | 5.42 | 8.42 | 11.02 | 12.6 |
| | 2001 | 6.56 | 12.87 | 13.2 | 16.43 |
| Waste generation (kg /capita/d) | 1994 | 0.66 | 0.48 | 0.32 | 0.44 |
| | 1999 | 0.61 | 1.1 | 0.55 | 0.52 |
| Garbage pressure (tons /km2) | 1999 | 17.529 | 4.042 | 16.548 | 13.708 |
| Waste collection (Gg per day) | 1999 | 3.124 | 5.327 | 3.692 | 6 |
| Mode of disposal (%) | Landfilling | 100 | 93 | 100 | 91 |
| | Composting | - | 7 | - | 9 |

Source: CPCB [1999].

Increase in MSW and population growth in Chennai. (Source: Jha et al. 2008)



Variation in the daily MSW collection in different months from 1996–2003 in Chennai (Source: Jha et al. 2008)



## Study at Delhi Landfills: Objectives

- The present emission inventory estimates for Indian waste sector has mostly used IPCC default values, that may not be representative of the Indian scenario. For realistic values for Indian conditions, detailed study is required to generate country specific emission factors.
- Assessment of temporal and spatial variation of GHG emissions.
- Reduction of uncertainties in trace gas emission inventories from the waste sector.
- Potential role of limiting factors (like, organic carbon, nitrogen, hydrogen, oxygen etc. ) in influencing the GHG emissions from landfills.

# Study area:

## Existing landfills in Delhi

**Bhalswa**

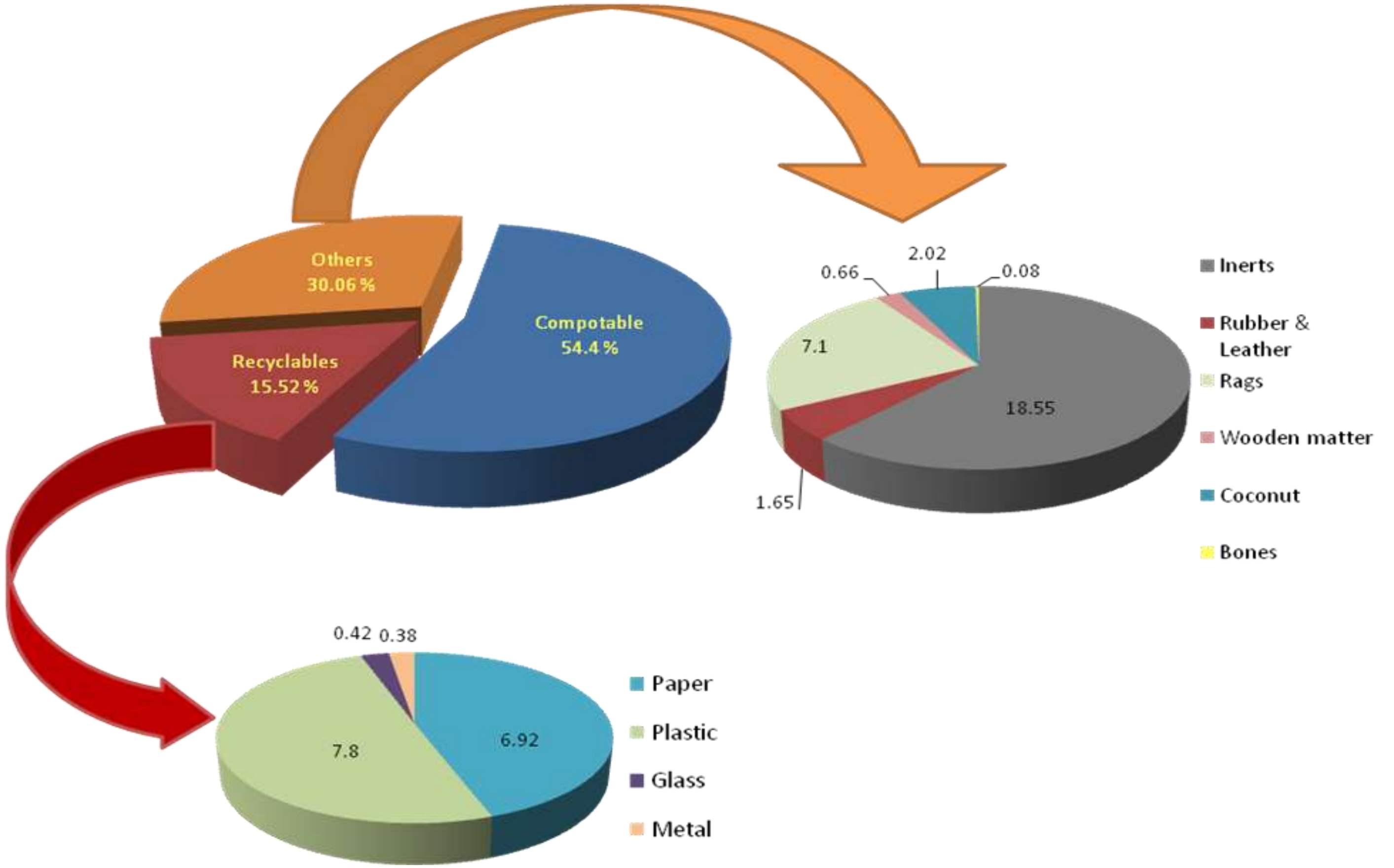
**Ghazipur**


**Area : 16.9 Ha**
**Disposal rate : 3200cum/day**
**Start year : 1992**

**Area : 29.6 Ha**
**Disposal rate : 5000cum/day**
**Start year : 1984**

**Area : 26.2 Ha**
**Disposal rate: 400cum/day**
**Start year : 1996**

**Okhla**




*Average Physical Composition of Municipal Solid Waste of Delhi, 2004- 2005*

# Sampling & Analysis of LFGs

Thermometer for monitoring box temperature

DC fan for homogeneous mixture

Sampling with syringe

Perspex box

Water column for isolation

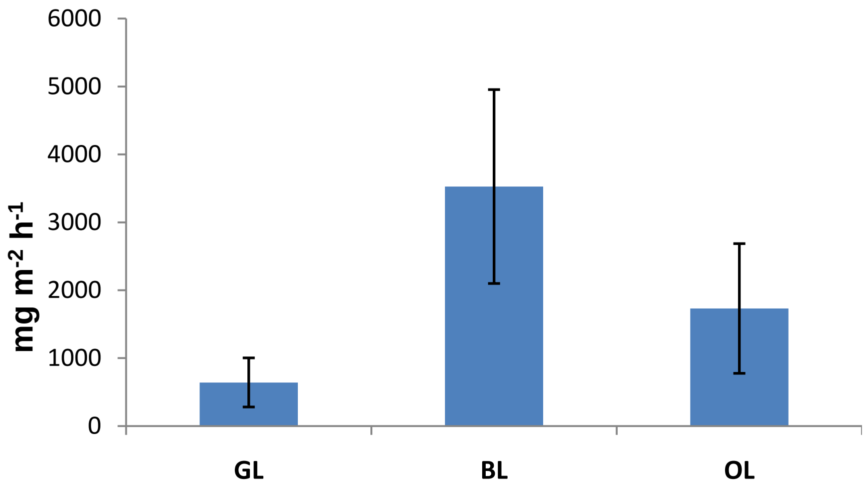
Aluminum base

LFG sampling at Okhla dumping site

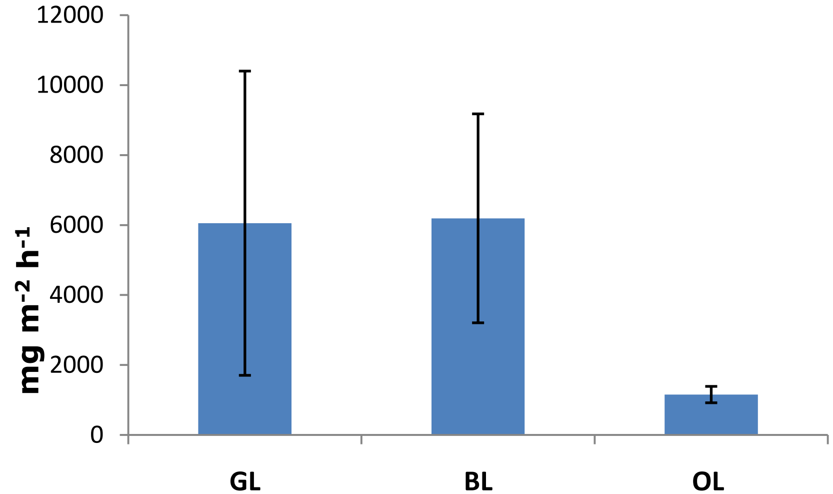
$CH_4$ & $CO_2$ gas standards

Gas chromatograph

Gas cylinders attached with GC

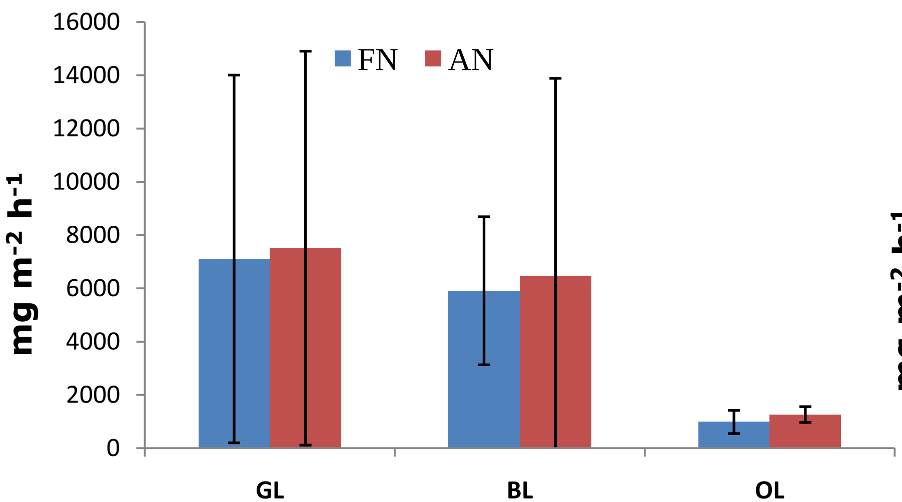



Methane emission flux comparison from three landfill sites in **winter season** in Delhi.

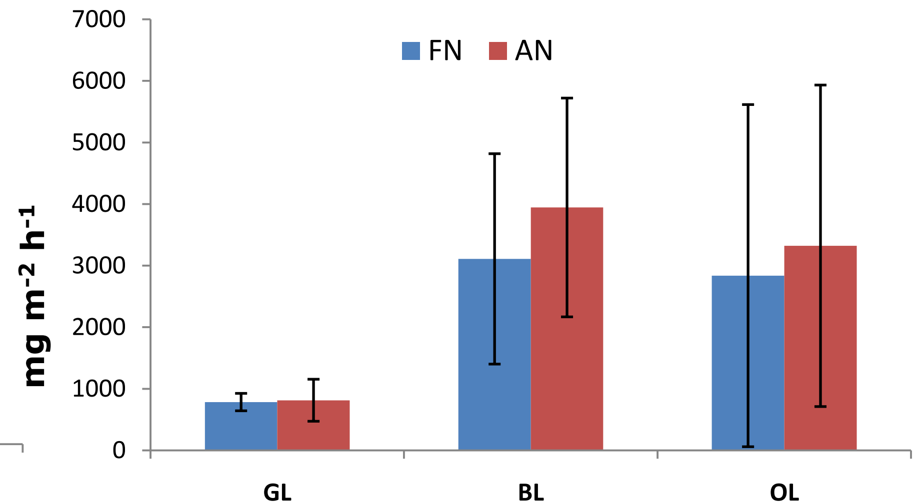



Methane emission flux in **summer season** from three respective landfills in Delhi.

## *Temporal and Spatial variability*




Forenoon –Afternoon methane emission flux during **summer season** .




Forenoon –Afternoon methane emission flux during **winter season** .

# GHGs emission from landfills in Chennai :

| Sampling site (Chennai) | | Kodungaiyur (KDG) | | Annual Average (ton/y) | Perugundi (PGD) | | Annual Average (ton/y) |
|---|---|---|---|---|---|---|---|
| Year of Study | | Dec. 2003 | Sep. 2004 | | Dec. 2003 | Sep. 2004 | |
| Study of Methane | $CH_4$ flux range ($mgm^{-2}h^{-1}$) | 2.4 -23.5 | 1.0 - 10.5 | 13.8 | 0.90 - 9.94 | 1.8 - 433 | 101.6 |
| | $CH_4$ Emission (ton /y) | 17.9± 9.9 | 9.7± 3.6 | | 7.27 ± 2.7 | 196 ± 145 | |
| Study of Carbon dioxide | $CO_2$ flux range ($mgm^{-2}h^{-1}$) | 39 -906 | 106 -242 | 627.0 | 102 to 544 | 12.3 to 964.4 | 533 |
| | $CO_2$ Emission (ton /y) | 924.0 ± 358.0 | 330.0 ± 67 | | 0.506 ± 0.123 | 0.560 ± 0.435 | |
| Study of Nitrous Oxide | N2Oflux range ($mgm^{-2}h^{-1}$) | 142 - 384 | 6 - 460 | 0.49 | 15 - 155 | 2.7 -1200 | 0.49 |
| | N2OEmission (ton /y) | 0.65 ± 0.17 | 0.32 ± 0.02 | | 70.20 ± 0.05 | 0.78 ± 0.52 | |

Source: Jha et al. 2008

# *GHG Emission Inventories and Climate Change Modeling*

# MAGICC/SCENGEN 4.1Based Assessment of Impacts of Indian Emissions on Future Climate Scenarios

MAGICC (**M**odel for the **A**ssessment of **G**reenhouse gas **I**nduced **C**limate **C**hange) is one-dimensional model of climate which estimates the changes in global mean temperature and sea level rise. It uses a series of reduced-form models to emulate the behaviour of fully three-dimensional, dynamic GCMs.

SCENGEN (**SCEN**ario **GEN**erator) in turn uses the global-mean temperature output from MAGICC to scale up the results from 17 transient GCMs to give global and regional output of temperature and precipitation on a 5° by 5° grid.

Involves development of emission inventories of Greenhouse Gases and other trace gas species for MAGICC/SCENGEN 4.1 model runs

Figure 4a. GLOBAL CARBON DIOXDE EMISSIONS FROM FOSSIL FUELS

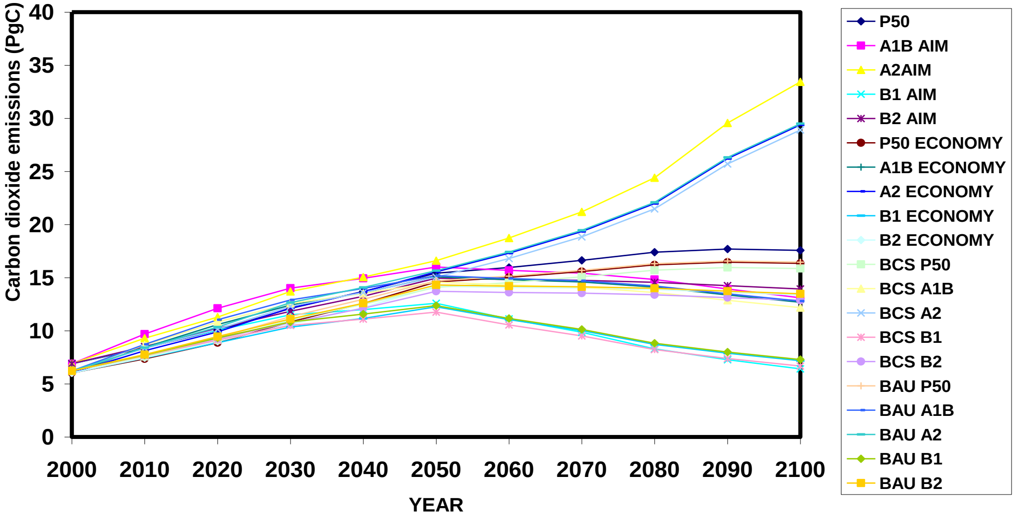



Figure 4e. GLOBAL CARBON DIOXIDE CONCENTRATION

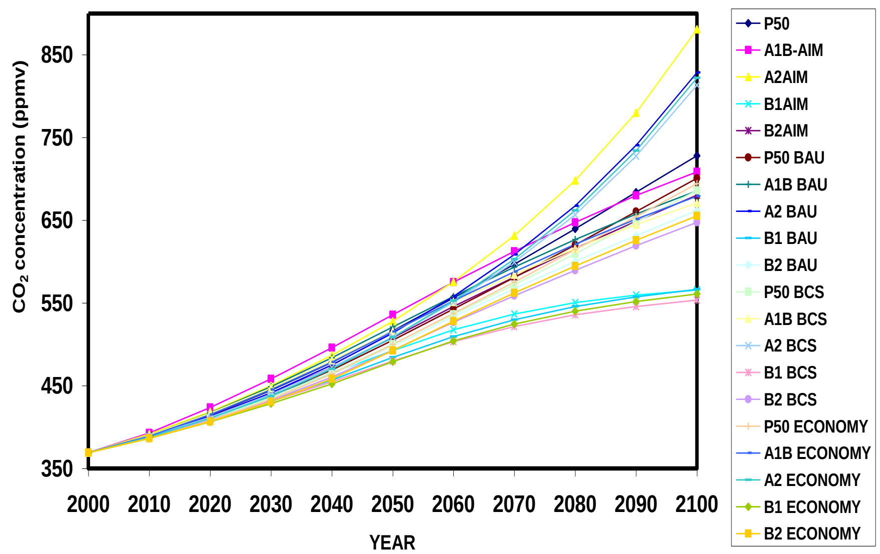
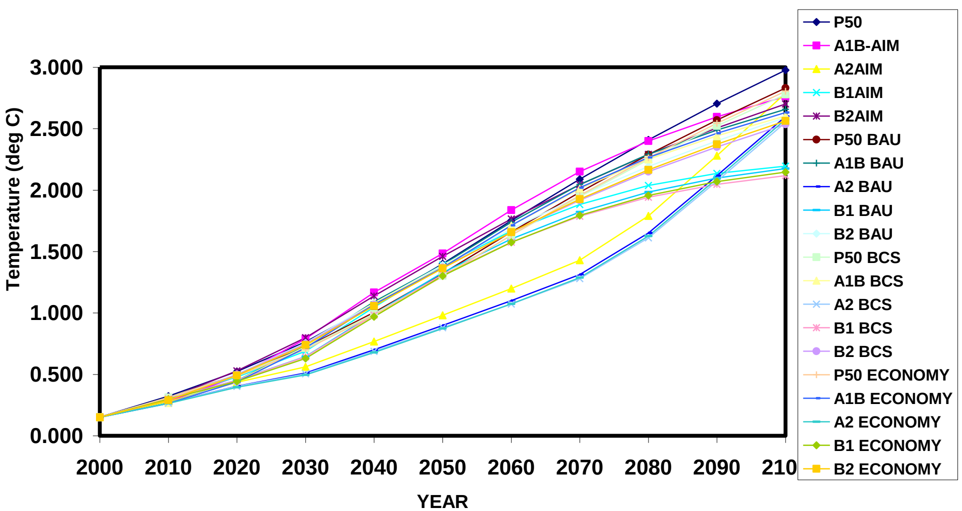
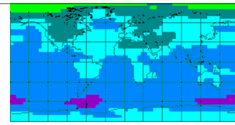
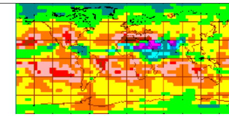
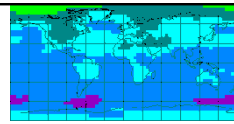
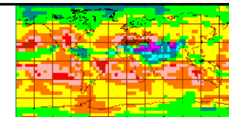
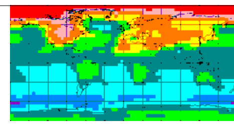
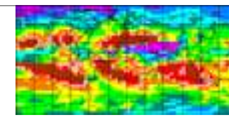
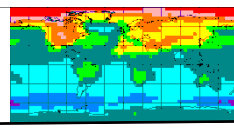
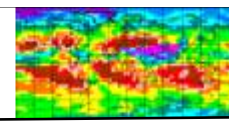
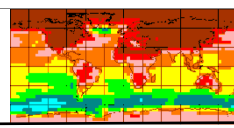
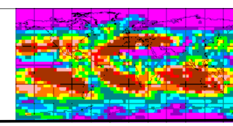
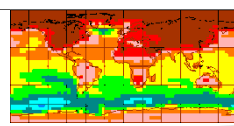
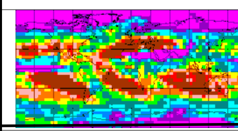
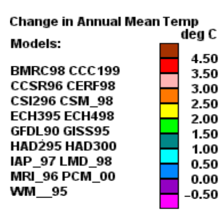
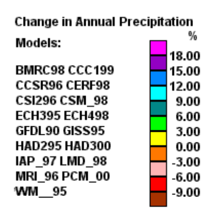



Figure 4k. GLOBAL MEAN TEMPERATURE CHANGE (INCOROPRATING AEROSOL EFFECTS WITH RESPECT TO YEAR 1990)



# SCENGEN Output for Annual Mean Temperature and Annual Mean Precipitation under Default and BCS Scenario

| Scenario | Change In Annual Mean Temperature | | Change In Annual Mean Precipitation | |
|---|---|---|---|---|
| Default P50 2020 |  | |  | |
| BCS P50 2020 |  | |  | |
| Default P50 2050 |  | |  | |
| BCS P50 2050 |  | |  | |
| Default P50 2100 |  | |  | |
| BCS P50 2100 |  | |  | |
| |  | |  | |

*To conclude:*

*Robust GHG Emission Inventories are need of the hour for understanding the Future climate change and its impacts*

*................thanks for your kind attention*