Uncertainty Assessment: India's Experience

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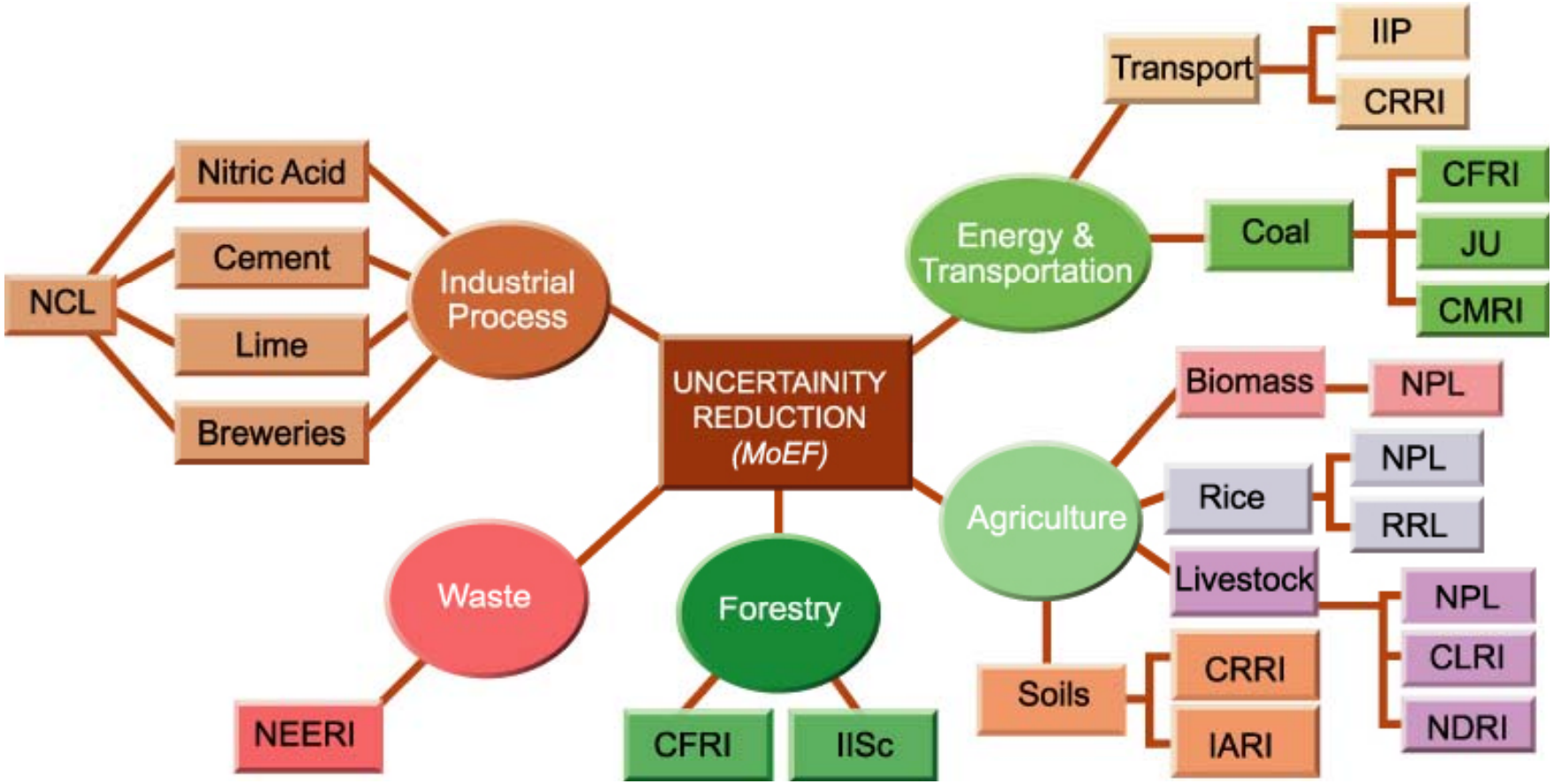
Approach towards reducing uncertainties in GHG estimates

- Development of country specific GHG emission factors
  - Updating the same with time
  - Evaluating key sources over time and developing new emission factors
- Identifying uncertainties in the steps of GHG estimates itself by using the IPCC guidelines

Activity	Unit	EF
Coal		
Coking coal	CO_2 (tC/TJ)	25.83
non Coking coal	CO_2 (tC/TJ)	26.13
Lignite	CO_2 (tC/TJ)	28.95
Developed by CMPRI, Dhanbad		
Transport		
Passenger Cars (Gasoline)	g CO_2/kg of Fuel	2752.98±179.35
	g CH_4/kg of Fuel	17.83
two wheelers (Gasoline)	g CO_2/kg of Fuel	1957.89±321.82
	g CH_4/kg of Fuel	86.45
Developed by IIP, Dehradun		
Coal Mining		
during mining		
degree 1	m3 CH_4/t coal mined	2.9
degree 2	m3 CH_4/t coal mined	13.1
degree 3	m3 CH_4/t coal mined	23.6
post Mining		
degree 1	m3 CH_4/t coal mined	0.98
degree 2	m3 CH_4/t coal mined	2.2
degree 3	m3 CH_4/t coal mined	3.1
Surface Mining		
during mining	m3 CH_4/t coal mined	1.8
post mining	m3 CH_4/t coal mined	0.2
Developed by CMPRI, Dhanbad		
Industrial Processes		
Cement production	tCO_2/ton of klinker	0.54±0.01
Lime production	tCO_2/ton quicklime	0.72
Lime stone and dolomite use	t CO_2/t ammonia	0.49±0.01
Ammonia Prod.	tCO_2/t ammonia	1.55
Nitric acid prod.		
Medium pressure plant	kg N_2O/ton of HNO3	10.1±3.8
High pressure plant	kg N_2O/ton of HNO3	2.8±1.3
high pressure /NSCR	kg N_2O/ton of HNO3	0.41±0.17
Developed by NCL, Pune		
Enteric Fermentation		
Indigenous		
Dairy	kg CH_4/yr/animal	28±5
Non Dairy < 1yr	kg CH_4/yr/animal	9±3
Non Dairy 1-3 yrs	kg CH_4/yr/animal	23±8
Non Dairy (others)	kg CH_4/yr/animal	32±5
Cross bred		
Dairy	kg CH_4/yr/animal	43±5
Non-dairy < 1 yr	kg CH_4/yr/animal	8±3
Non Dairy1-3 yrs	kg CH_4/yr/animal	22±5
Others	kg CH_4/yr/animal	44±11
Developed by: NDRI, Karnal; NPL, New Delhi; CLRI, Chennai		
Rice Cultivation		
Rain fed - flood prone	ton CH_4/km2	19±5.0
Rainfed-drought prone	ton CH_4/km3	6.95±1.86
Irrigated (Continuously Flooded)	ton CH_4/km4	17.48±4.00
Intermittently Flooded - Single aeration	ton CH_4/km5	6.62±1.89
Intermittently Flooded- Multiple Aeration	ton CH_4/km6	2.01±1.49
Deep water	ton CH_4/km7	19±5.0
Developed by: NPL, New Delhi		

NATCOM-I

Institutional arrangement: NATCOM I



Moving on to NATCOM - II

- Refinement of existing factors
- Development of new emission factors
- Moving towards higher tier estimates for key source categories
- Bridging data gaps identified in NATCOM I
- Launching standard QA/QC procedures for each of the categories

Table 1: Key source analysis of the 1994 GHG inventory (NATCOM, 2004)

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 I	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 and Forestry	14292	1.2	1161186	94.5	Tier I	D	CS
Coal mining	13650	1.1	1174836	95.6	Tier III	CS	CS
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

Note: D: IPCC default emission factor, CS: Country specific emission factor, R : Revised country specific emission factor

Key Sources analysis

Planning for reducing uncertainties

Sources of emission	EF used in INC	Status of EF envisaged in SNC	Activities proposed in SNC	Rationale	Tier used in INC	Proposed in SNC
Energy and transformation industries	CS	R	o Refinement of NCV of different types of coal o Determine technology specific point source level EFs of CO_2, CO and NOX for thermal power plants	o Inadequate sample size taken in INC o Thermal power plants is the key category within the energy and transformation sector	Tier I	Tier II
Enteric Fermentation	CS	R	o Sample survey of age wise domestic livestock population, feed type, milk production in various climate regions of India o Develop CH_4 EF for enteric fermentation through estimation and measurement	o It is a key category in the agriculture sector. o In INC, appropriate activity data was not available to make a correct assessment o The sample size for which measurements were taken was small, and could not be validated through estimates because lack of activity data	Tier II	Tier III
Industry (fuel combustion)	D	D	-not targeting-	-not targeting-	Tier I	Tier I
Rice Cultivation	CS	R	Undertake CH_4 flux measurements in hotspot areas	This is the second largest GHG emitting category amongst all the agriculture categories. As the emission from this source is dominated by emissions from hotspots, therefore it is proposed to investigate the EFs from these regions.	Tier II	No change
Transport	CS	R	o Conduct survey to apportion the fossil fuel used in various types of road vehicles o Refine EFs from different kinds of gasoline and diesel driven vehicles by incorporating driving cycles	These two approaches will be used to reconcile the top down and bottom up emission estimates from this source	Tier I	Tier II
Emission from Soils	D		o Development of N_2O EFs from	This is a major source of N_2O emission	Tier I	

Planning for reducing uncertainties

		CS	different soils	amongst all the categories.		Tier II
Iron and steel production	D	CS	○ Plant level assessment of CO_2 EFs (resulting from combustion of fuel & production process)	It is a fast growing sector of the economy in addition to being a major source of CO2 emission	Tier I	Tier II
Energy use in Residential sector	D	D	-not to be targeted-	-not to be targeted-	Tier I	No change
Biomass burnt for energy	D	D	-not to be targeted-	Data available	Tier I	No change
All other energy sectors	D	D	-not to be targeted-	Individually not in key category	Tier I	No change
Cement production	CS	R	Plant level assessment of CO_2 EFs due to production process	It is a fast growing sector of the economy in addition to being a major source of CO2 emission	Tier I	Tier II
Energy consumed in Commercial-institutional	D	D	-not to be targeted-	-not to be targeted- As source category too diverse, and enough resources not available.	Tier I	No change
Manure Management	D	D	-not to be targeted-	Manure management not done in a systematic manner in India	Tier I	No change
Ammonia production	D	CS	Determine plant level CO_2 EF	Key category – not targeted in INC.	Tier I	Tier II
Land use, Land-use change and Forestry	D	CS	○ Develop land use change matrix ○ Assess biomass stock, carbon fraction of biomass, biomass growth rates of various types of species (crops/forests) to be considered under this category	A key category, and targeted in SNC to bring in the GPG LULUCF (2003) guidance in the inventory estimation process.	Tier I	Tier II
Coal mining	CS	CS	-not targeted-	-not targeted-	Tier III	Tier III
Oil and natural gas system	D	D	Develop methodology for assessing data on a regular basis on oil and natural gas transport, storage, venting and flaring.	Though not a key category, but the consumption of oil and natural gas shows the highest growth rate w.r.t other fossil fuel, so efforts will be made to stream line assessment of activity data	Tier I	Tier I

Planning for reducing uncertainties

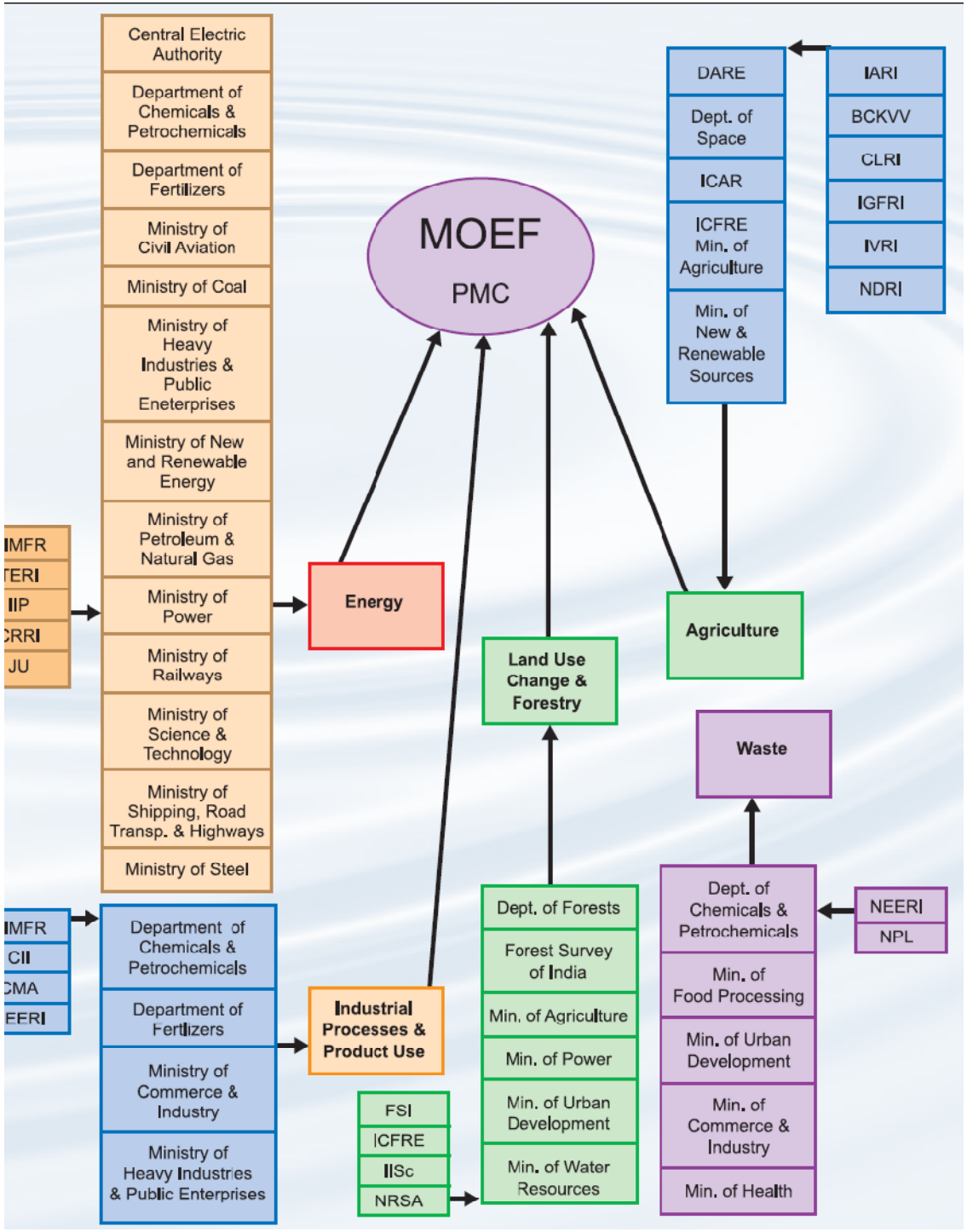
Municipal Solid Waste Disposal			○ Assess per capita MSW generation, composition and handling process ○ Generate EFs for managed and unmanaged landfill areas	Rapid urbanization resulting in increased generation of waste and changed composition	Tier I	Tier II
Domestic Waste water	D	D	-not targeted-	-not a key category-	Tier I	No change
Lime stone and dolomite use	D	D	-not targeted-	not a key category-	Tier I	No change
Agricultural crop residue	D	D	-not targeted-	not a key category-	Tier I	No change
Nitric acid production	CS	CS	-not targeted-	not a key category-	Tier II	No change
Human Sewage	D	D	-not targeted-	not a key category-	Tier I	No change
Lime production	D	D	-not targeted-	not a key category-	Tier I	No change
Industrial Waste Water	D	CS	Chemical analysis of waste water in selected key industries	Rapid growth of certain industries like paper, pulp, beverage etc.	Tier I	Tier II
Ferro alloys production	D	D	-not targeted-	not a key category	Tier I	No change
Aluminium production	D	D	-not targeted-	not a key category	Tier I	No change
Carbide production	D	D	-not targeted-	not a key category	Tier I	No change
Soda ash use	D	D	-not targeted-	not a key category	Tier I	No change
Black carbon and styrene production	D	D	-not targeted-	not a key category	Tier I	No change

NATCOM-II

- Improving NCV of coal
- CO2 emission factors from two power plants due to combustion of coal
- CO2 emission factor from an integrated iron and steel plant due to combustion of fuel and the processes itself
- Updating CH4 from Coal mining
- CH4 from transport of oil/natural gas

NATCOM-II

- CH4 from continuously irrigated rice fields
- N2O from agricultural soils
- Improving CH4 EF from enteric fermentation in Livestock
- Soil C from Forests
- CH4 from MSW
- CH4 from Waste water from key industries



Institutional Arrangement: NATCOM II

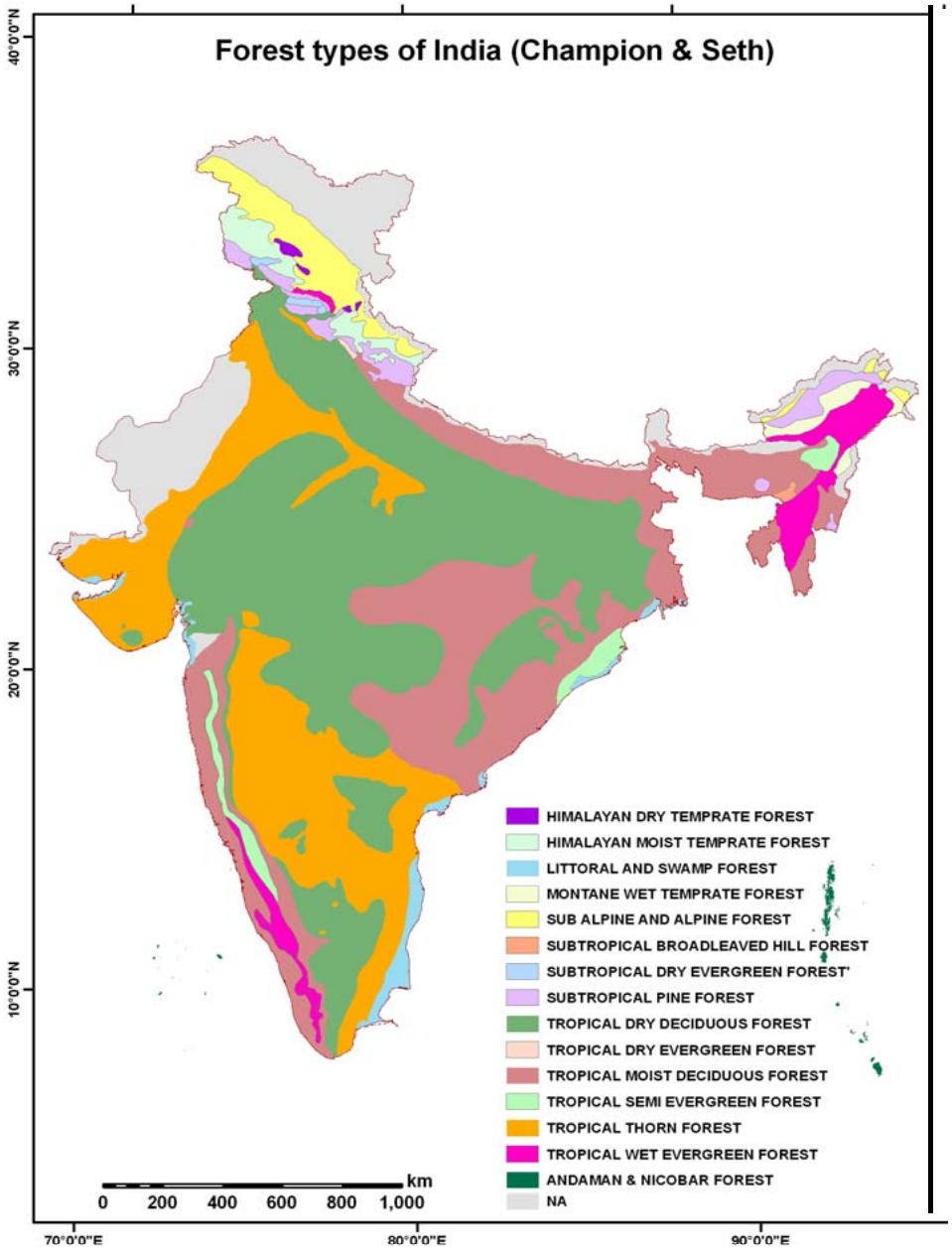
An example – LULUCF – Soil C

Problems to address..

- ✓ Preparation of Forest type and sub-group type map of India (Champion & Seth, 1968)
- ✓ Harmonization of different spatial layers of India (forest types, actual forest cover, administrative boundaries and collateral data sources), and assigning them uniform spatial standards
- ✓ Non-existence or localized presence of some of the forest sub-group types and difficulty in locating them
- ✓ Even modern tools like RS and recent published estimates gives only forest types and sub-group type associations/equivalents

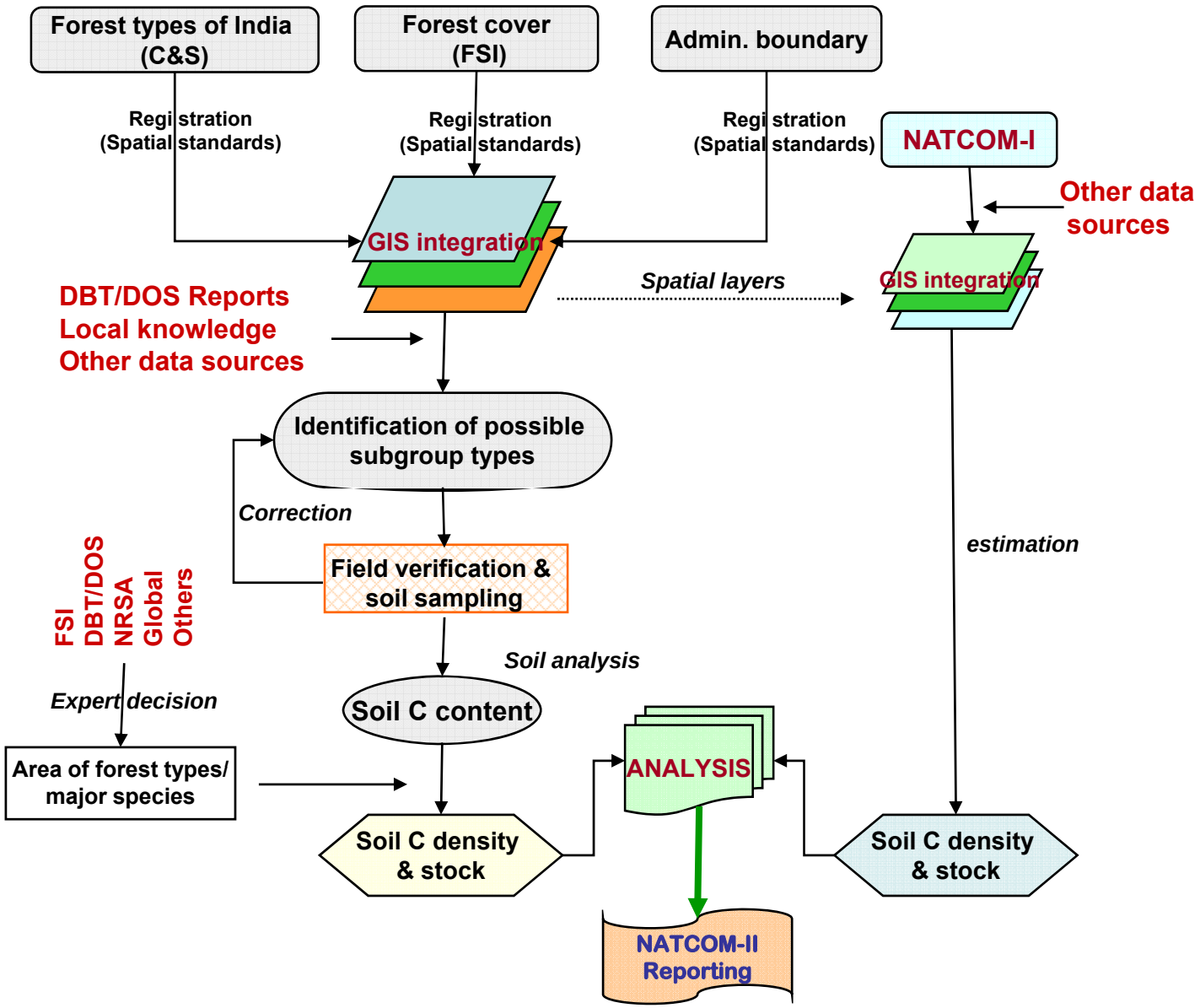
Opportunities..

- ✓ Preparation of Forest type map and sub-group type details of India in tabular format (Champion & Seth, 1968)
- ✓ Harmonization of different spatial layers of India (forest types, actual forest cover, administrative boundaries and collateral data sources) in GIS and assigning them uniform spatial standards
- ✓ Use of FSI and DBT-DOS reports

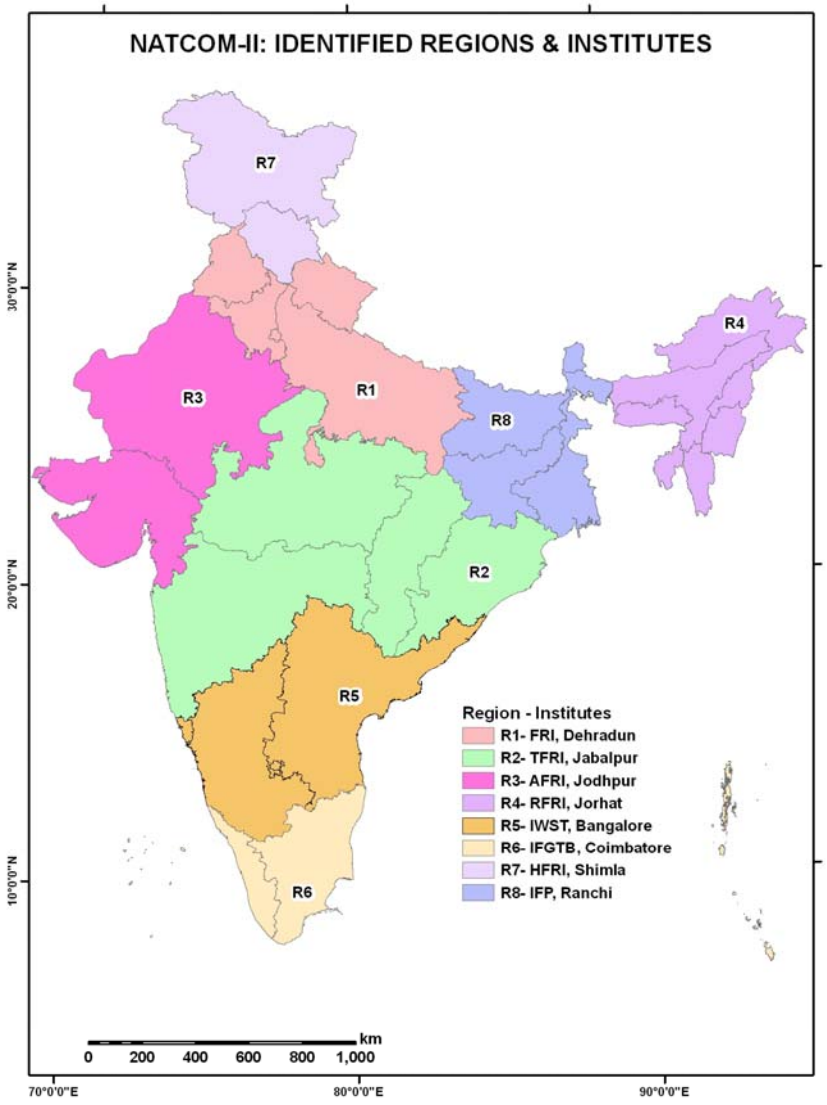

Forest types of India (Champion & Seth)
40°0'0"N
30°0'0"N
20°0'0"N
10°0'0"N
70°0'0"E
80°0'0"E
90°0'0"E
HIMALAYAN DRY TEMPRATE FOREST
HIMALAYAN MOIST TEMPRATE FOREST
LITTORAL AND SWAMP FOREST
MONTANE WET TEMPRATE FOREST
SUB ALPINE AND ALPINE FOREST
SUBTROPICAL BROADLEAVED HILL FOREST
SUBTROPICAL DRY EVERGREEN FOREST'
SUBTROPICAL PINE FOREST
TROPICAL DRY DECIDUOUS FOREST
TROPICAL DRY EVERGREEN FOREST
TROPICAL MOIST DECIDUOUS FOREST
TROPICAL SEMI EVERGREEN FOREST
TROPICAL THORN FOREST
TROPICAL WET EVERGREEN FOREST
ANDAMAN & NICOBAR FOREST
NA
km
0 200 400 600 800 1,000


Forest spread
N
AFGHANISTAN
PAKISTAN
CHINA
NEPAL
TIBET
BHUTAN
BANGLADESH
MYANMAR
Jammu & Kashmir
Himachal Pradesh
Punjab
Chandigarh
Uttaranchal
Haryana
Delhi
Rajasthan
Uttar Pradesh
Bihar
Sikkim
Arunachal Pradesh
Assam
Nagaland
Meghalaya
Manipur
Mizoram
Tripura
Jharkhand
West Bengal
Gujarat
Madhya Pradesh
Chhattisgarh
Orissa
Dadra & Nagar Haveli
Daman & Diu
Maharashtra
BAY OF BENGAL
ARABIAN SEA
Andhra Pradesh
Goa
Karnataka
Pondicherry
Tamil Nadu
Kerala
Lakshadweep
Andaman & Nicobar Islands
INDIAN OCEAN
Very Dense Forest
Mod. Dense Forest
Open Forest
Scrub
Non-Forest
Water-bodies
State boundary

Flow diagram showing overview of methodology



ICFRE participating Institutes and their area of jurisdiction



Nodal ICFRE Institutes and number of sample locations

Region	Name of the Institute	Area coverage	No. of subgroup types	Number of samples (@ 3 per type + from non-forest area)
R1	FRI, DEHRADUN	UA, UP, PUN,HA, ND, Chandigarh	31	33+10=43
R2	TFRI, JABALPUR	MP, MS, OR,CH	17	51+10=61
R3	AFRI, JODHPUR	RA,GU, D&N Haveli, D&Diu	18	54+10=64
R4	RFRI, JORHAT	North East	29	87+12=97
R5	IWST, BANGALORE	KA, AP, GOA	15	45+08=53
R6	IFGTB, COIMBATORE	TN, KE, A&N Is. Pondy,	32	96+10=106
R7	HFRI, SHIMLA	HP, J&K,	16	48+08=58
R8	IFP, RANCHI	BH, JH, WB, Sikkim	13	39+10=49
	Total No. of samples		**171**	**513+78=591**

What is given…

- Forest types, sub-groups, sub-group types, C & S code, distribution and dominant species along with the identified institute is supplied to every participating institutes.
- This will be supplemented with any other map available for now or as soon is become available.

Detailed methodology Prepared for :

- Sample collection
- Storage
- Analysis and calculation

Inception meeting with Nodal officers from different ICFRE Institutes conducted 9-10 May

Sampling procedure to be uniformally adopted by all teams demonstrated in the field

QA/QC plan developed

Annexure – I

Basic information about the soil samples and sampling site

Compartment/Village_____**Block/Tehsel**_____
Division/Distt._____**State**_____
Altitude_____**Aspect** _____**Latitude**_____ **Longitude**_____
Forest type :_____ Dominant species_____
Slope (%) : _____ Rock out crop (%) : _____
Coarse Fragments (%)_ _____
Tick on appropriate feature:
a) Erosion class : Slight Moderate Severe Gullied
b) Physiographic: Hill top Hill slope Plateau Plain Valley
c) Moisture : Wet Moist Dry
d) Plant litter : Light (25 % surface area coverage)
Moderate (25-50 % surface area coverage)
Heavy (>50 % surface area coverage)
e) Soil depth: Shallow (<25 cm.) , Moderately deep (25-50)
Moderate (50-100) Deep (>100 cm)
Sample Collected By:
Division:_____
Institute:_____
Date_
Soil Sample No.: _____ (Region No./ Forest types / Sample No.- Replication No.)
Foe ex. (R6/ TEG / 1-2)
Note: Separate sheet should be filled at each sampling site and handed over in lab with samples

Soil Sample Collection Protocol

Most carbon accounting purposes require a volumetric estimate of soil carbon. This requires measures of bulk density and the volumetric proportion of coarse fragments (e.g. gravels).

Existing guidelines (IPPC, 1997) for carbon accounting refer only to the upper 0.30 m. This zone is intended to cover the actively changing soil carbon pool.

SOC Density (t/ha) = Organic Carbon Content (%) * Bulk density * Soil Layer depth * (1- volume fraction of coarse fragments)

While sampling certain points should be kept in mind.

- *Locate sample site away from roads, houses and construction sites, etc.,*
- *In a forested area sample should be drawn away from the trunk of the tree or between trees.*
- *Avoid eroded and locations where large plant material is under decay.*
- *Always dig **a fresh rectangular pit** and in grass land first clear the top layer and dig the profile.*

1. Estimating Rock Outcrop

It is desirable to have a more accurate estimate of the volume of rock within the soil individual. Measure rock outcrop along a series of linear transects. At each transect intercept, record the length of rock surface (>50 mm). The area of rock outcrop is estimated using:

$$\mathbf{\mathit{Aro} = 100\ (\sum r\ /\ L)}$$

where *Aro* is the areal percentage of of rock outcrop, *L* is the total transect length and *r* is the length of rock intercepted (m).

Rock outcrop can also be measured using the 10 m grid (100 m^2 area) assuming that the observer is at the middle of the grid. Make schematic sketch of the rock out crop on the grid and estimate the percentage.

2. Estimating Percent Coarse Fragment in the Soil

Percent coarse fragment (>2mm size) in soils will be estimated by morphological examination of soil.

Coarse fragments by volume in layer of 0-30 cm. using the visual estimation of coarse fragments key should be observed.

An area of 10 cm. by 10 cm. (100 cm2) can be visualized in layer covering of coarse fragments.

It is also useful to indicate the size of coarse fragments (CF) by type, as given in table 4b:

Type of coarse fragments and its size

Gravels (G) *2 -75 mm*; Cobbles (C) *75-250 mm*; Stones (S) *> 250 mm* (25 cm).

3. Collection of Samples

In each sampling units, three sampling points will be selected as replicates.

At each point soil sample of 0-30 cm. depth will be collected.

One sample will also be collected in non-forested area (agricultural area) close to the major forest types.

Detailed number of samples, forest sub types and nodal institutes are given in sampling plan with participating institute.

3.1 Soil sample for carbon estimation:

- Forest floor litter of an area of 0.5m x 0.5 m, at sampling point will be removed and a pit of 30 cm wide, 30 cm deep and 50 cm in length will be dug out.

- Soil from three sides of the pit, will be scraped with the help of Kurpee from 0 to 30 cm depth and bulked. Scrap uniform thickness of soil layer from top to bottom (0-30m cm)

- This soil will be mixed thoroughly and removed gravels. Quarter the bulked soil sample and select opposite quarter approximately of 500 gm. Here, coarse fragments can also be approximated.

- Keep in a polythene bag and tightly closed with thread.

- A label showing the sampling details should be put in side of polythene bag before closing the bag.

- Proper entry to be made in field note book

3.2 For bulk density estimation by Core sampler

3.3 Storage of the samples

- If numbers of samples are large and not possible to analyze / process immediately after collection from field, then samples collected for soil organic carbon, should be placed in refrigerator or deep freezer.

- Taken out desired numbers of sample and prepare them for estimation.

4. Preparation of sample

4.1 Carbon estimation in the laboratory

- Open the polythene bag and spread the samples on a brown paper sheet in the laboratory. Let the sample dry at room temperature in the laboratory.
- *Avoid direct sun drying or oven drying.*
- Marking of the sample (which was given on the label at the time of the collection of sample) should be written on the brown paper sheet to avoid the mixing of the samples.
- After drying the samples, grind it and sieve it through 100 mesh sieve (2 mm sieve). This sieved sample will be used for soil organic carbon estimation.

4.2 Analysis

Soil organic carbon will be estimated by standard Walkley & Black method and

Vegetation characteristics of the sample site

Measure 22x22m either side of sample location (Quadrat of 31x31 m=0.1 ha)

Enumerate all tree species > 10 cm dia within the quadrat

For shrubs 5x5 m qudart

For herbs and grasses 1x1 m quadrat

Thank You