Methodological issues on monitoring forest cover and forest carbon stocks

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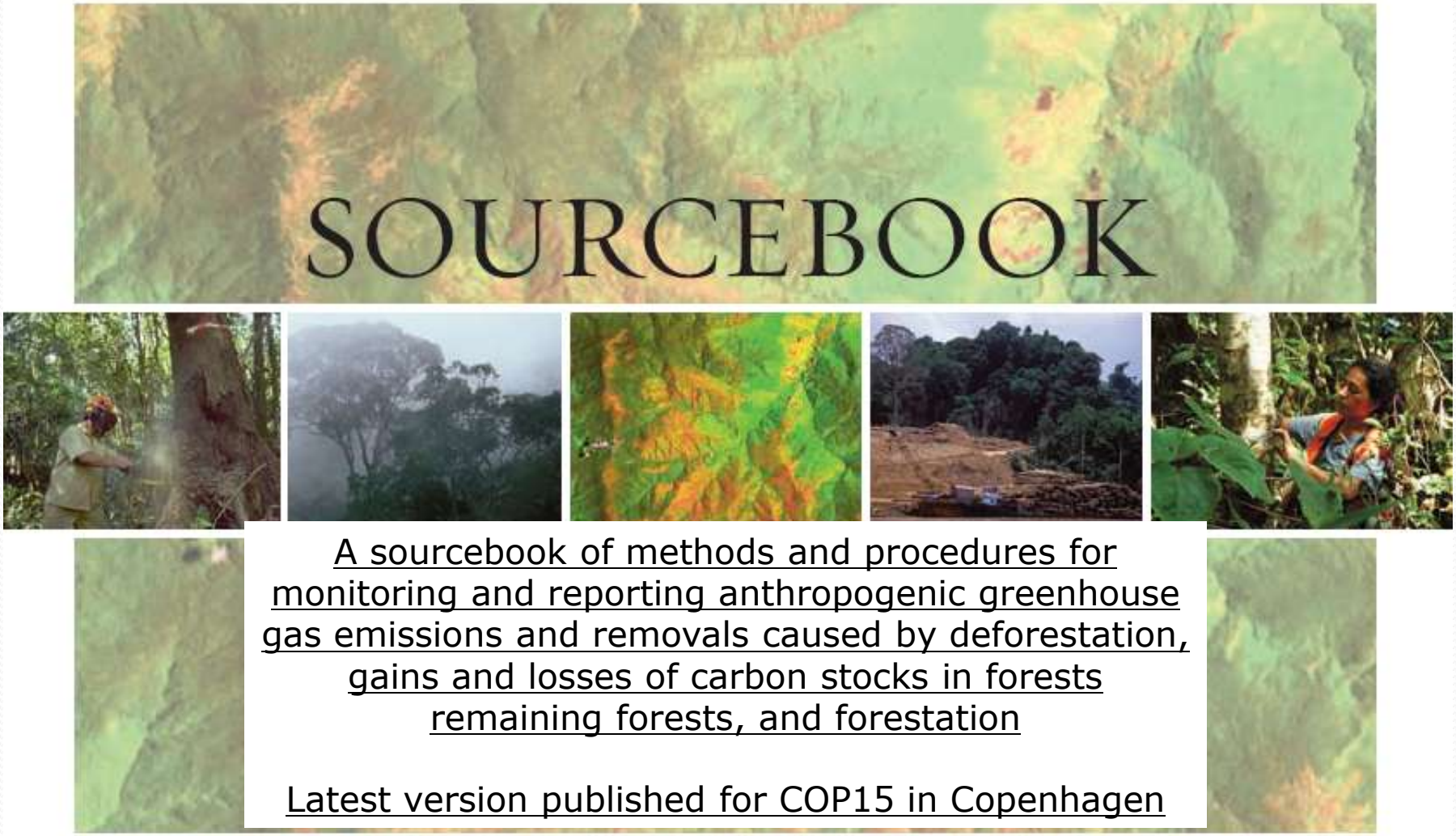
GOFC-GOLD REDD Sourcebook



A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation

Latest version published for COP15 in Copenhagen

GOFC-GOLD Global Observation of Forest and Land Cover Dynamics-

A technical panel of the Global Terrestrial Observing System (GTOS) and supported by FAO, UNEP, START, ESA and NASA.

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Web resources

- **GOFC-GOLD:**
  - http://www.fao.org/gtos/gofc-gold/
- **GOFC-GOLD land cover project office:**
  - http://www.gofc-gold.uni-jena.de/
- **GOFC-GOLD REDD sourcebook:**
  - http://www.gofc-gold.uni-jena.de/redd
- **IPCC background paper on use of remote sensing in LULUCF sector (GOFC-GOLD 33):**
  - http://www.fao.org/gtos/gofc-gold/series.html
- **UNFCCC/SBSTA technical paper on costs of monitoring for REDD**
  - http://unfccc.int/resource/docs/2009/tp/01.pdf

Guiding principles (IPCC) for monitoring the forest cover and forest carbon stocks

- consistency in measurements,
- transparency in reporting,
- comparability due to common methodological approach
- completeness in measuring all carbon pools and
- robustness- based on scientific principles

Monitoring forest area change / activity data using remote sensing imagery

- **Monitoring of changes of forest areas- deforestation**
- **Monitoring of increase of forest area- forestation**
- **Monitoring of forest area change within forests- forest degradation**

Considerations essential for monitoring on a scientifically credible basis

- The national circumstances, particularly existing definitions and data sources
- Selection and acquisition of satellite imagery and coverage
- Available skilled staff and soft and hardware resources
- Sampling based or wall to wall coverage
- Image interpretational technique
- Accuracy assessment

Optical mid-resolution (10-60 m) sensors presently available

Nation	Satellite &sensor	Resolution and coverage	Cost for data acquisition	Features
USA	Landsat-5 TM	30 m 180 X 180 km^2	All data archived at USGS is free	Images down loadable to any satellite receiving station at repetivity of 16 days
USA	Landsat-7 ETM+	30 m 60 X 180 km^2	All data archived at USGS are free	Data gaps outside of the central portion of the images due to failure of scan line corrector in April 2003
USA/Japan	Terra ASTER	15 m 60 x 60 km^2	60 US$/scene	Data acquired on request and is not routinely collected for all areas
India	IRS-P6 LISS-III AWIFS	23.5 m 141 X141 km^2 56 m 740 X 740 km^2	152 US$/scene 322 US$/scene	Images available from 2003 from NRSC. Images of earlier satellites IRS IC/ID with same resolution also available since 1997
China/Brazil	CBERS-2 HRCCD	20 m	Free in Brazil and Potentially for other developing countries	Experimental: Brazil uses on demand to bolster their coverage
France	SPOT-5 HRVIR	10-20 m 60 X 60 km	2000 €/scene	Commercial, Indonesia and Thailand uses along with Landsat

- **Other types of sensors such as Radar (ERS1/2 SAR, JERS-1, ENVISAT-ASAR and ALOS PALSAR) and Lidar are potentially useful and appropriate.**

- Coarse resolution (250 m – 1km) data available from 1998 (SPOT – VGT) or 2000 (MODIS) have utility because high temporal resolution (1 to 2 day)

- Fine resolution data obtained from IKONOS, QuickBird, Worldview, Geoeye-I, Cartosat but expensive to cover large areas- used to calibrate algorithm and ground truthing

Wall to wall or sampling approach?

- Wall to wall approach- covers the full spatial extent of the forested areas and is a common approach
- A few large countries like India and Brazil have established operational wall-to-wall system since 1980s based on mid-resolution satellite imagery (India-biennial and Brazil- annual)
- If resources are insufficient, the sampling approach is equally efficient specially for large countries.
- The recommended sampling approaches are systematic and stratified sampling.

Analysis of the satellite imagery

- The selection of the method depends on the available resources including software for image processing.
- A combination of automated methods (segmentation or classification) and visual interpretation gives the best result.
- An independent accuracy assessment is an essential component to link area estimates to a crediting system.

Monitoring of forest area change- special situations

- **Monitoring of increase of forest area- forestation**
  - Identifying increase in forest area with satellite imagery is generally difficult canopy closure slow- better with high resolution
- **Monitoring of forest area change within forests- forest degradation**
  - Only those areas can be identified by satellite- where intensity of degradation is high and but not all of them
  - Demands use of more sophisticated algorithm and high resolution imagery
  - Spectral mixture analysis (SMA) has been found to be the robust technique.

Monitoring forest carbon stock

- **Estimation of above ground biomass**
- Woody biomass of living trees above ground
- Biomass of non tree understory vegetation (herb, shrub, climber)
- Biomass of deadwood, woody debris and litter

- **Estimation of below ground biomass**
- Below ground biomass (root system)
- Soil organic carbon

Data needs for meeting the requirements of the three IPCC Tiers

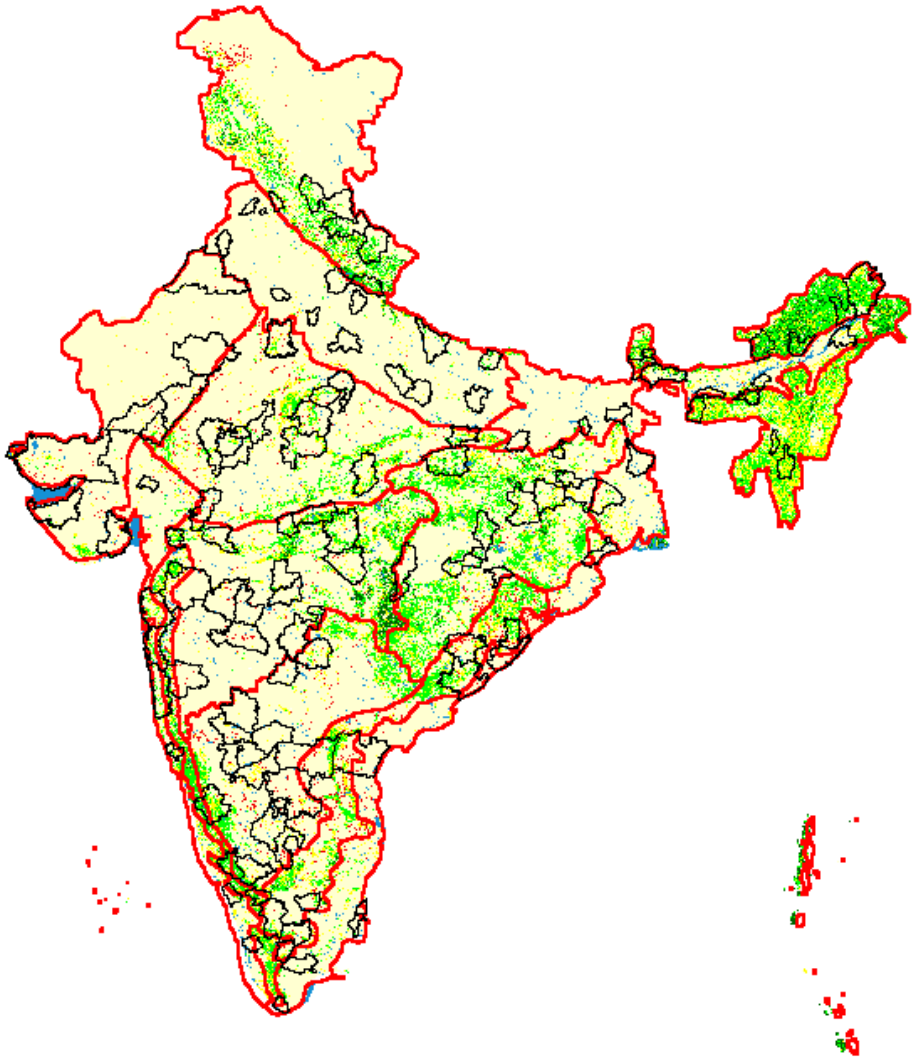
Tiers	Data needs / examples of appropriate biomass data
Tier 1 (basic)	Default values given for all the vegetation-based pools including MAI and biomass of specific forest type
Tier 2 (intermediate)	MAI and or biomass from existing forest inventories or ecological studies as well as newly collected forest biomass data and default values for all non- tree pools
Tier 3 (most accurate)	Repeated measurements of trees from permanent plots and calibrated process models. Can use default data for other pools stratified by in country regions and forest type, or estimate from process models.

National Forest Inventory- Example INDIA

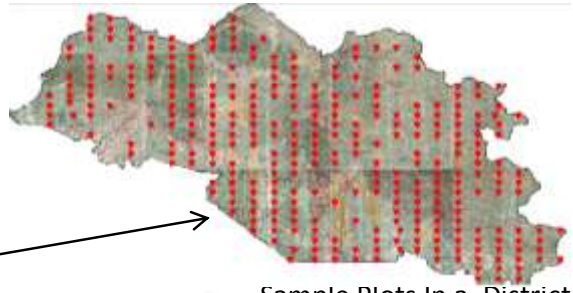
- The country has been stratified into 14 physiographic zones based on vegetation, climate and topography
- Ten percent (60) districts are covered in every two year cycle.
- The districts are selected randomly within each zone with in proportion to their size.
- Topographic sheets of 1:50,000 scale forms the base map for the inventory.
- Systematic sampling is followed to lay out sample plots of size 0.1 ha

National Forest Inventory - Methodology -contd

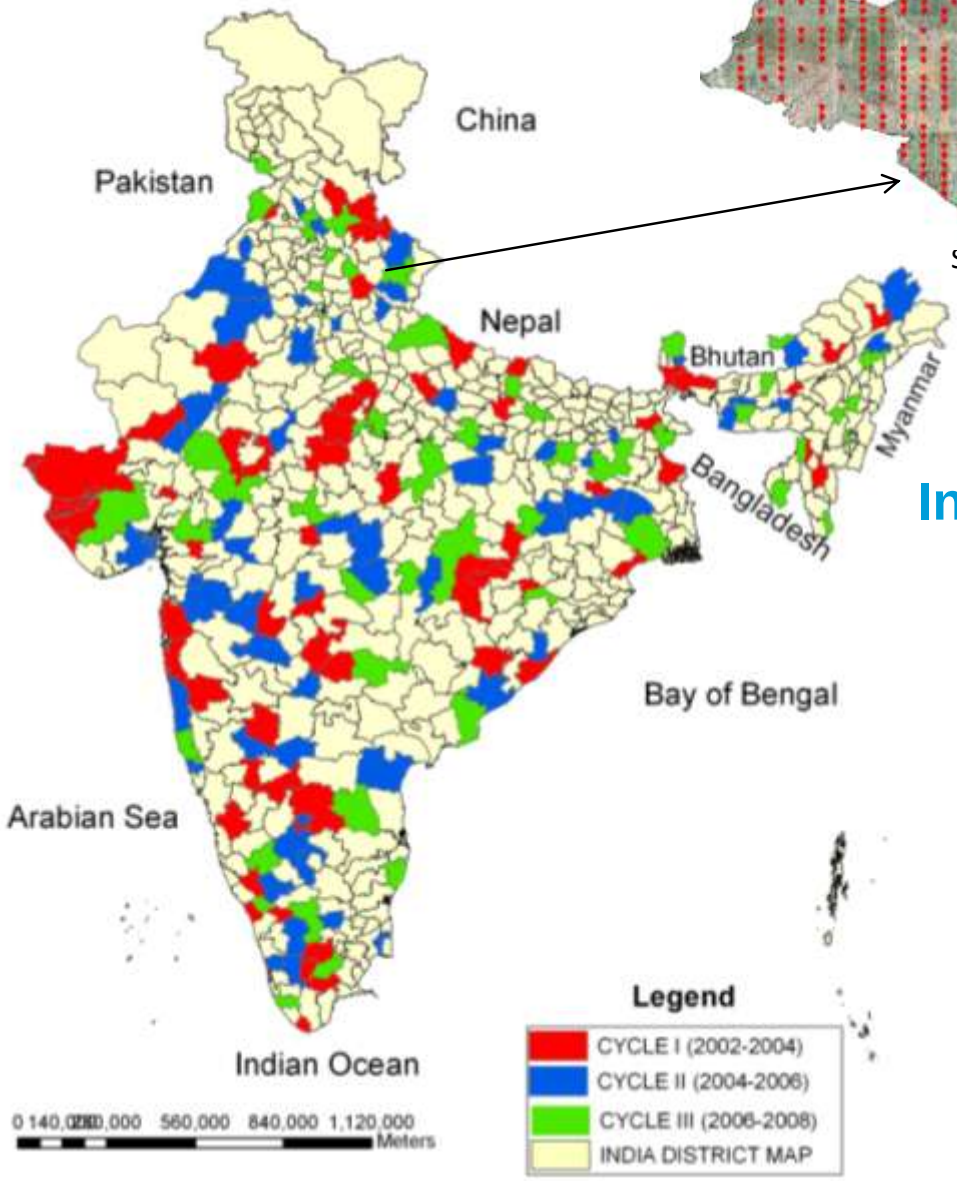
Randomly Selected 60 districts



Districts Completed Under National Forest Inventory



Sample Plots In a District



Inventory of 179 districts completed out of 600

Sample plots = 22,000

Methodology of NFI -- contd

- **Use of the suitable volume equation is most critical for accurately estimating the volume (biomass) of the tress.**
- **More than 250 volume equations have been developed by FSI of tree species growing in different physiographic zones are used for estimating growing stock.**
- **In FSI these volume equations $V = f(D, H, F)$**

  are based on measurement of trees above 10 cm dbh and excludes volume of main stem below 10 cm and branch wood below 5 cm diameter.

VOLUME EQUATIONS FOR FORESTS OF INDIA, NEPAL AND BHUTAN

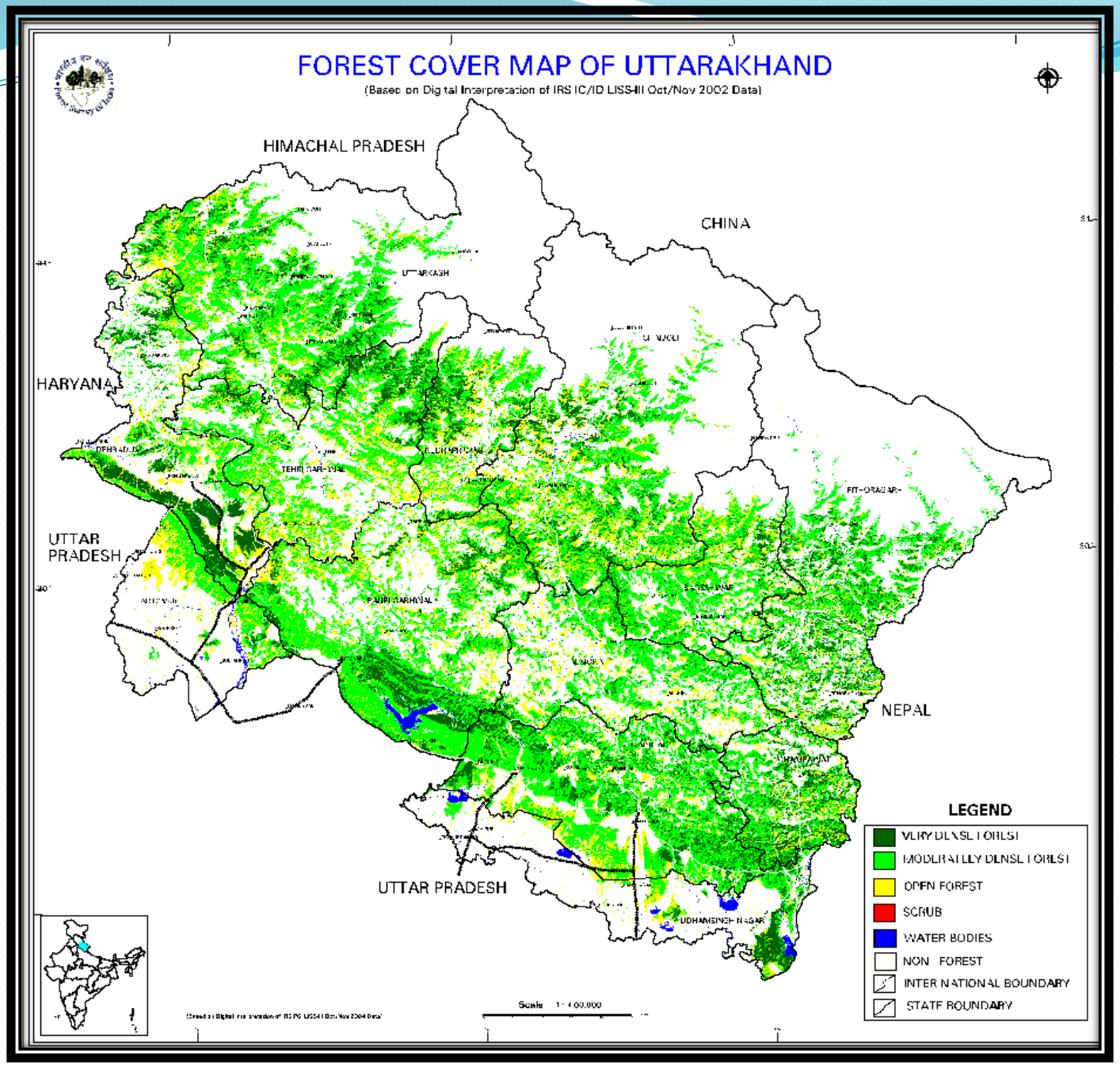
FOREST SURVEY OF INDIA
MINISTRY OF ENVIRONMENT AND FORESTS
GOVT. OF INDIA
1996

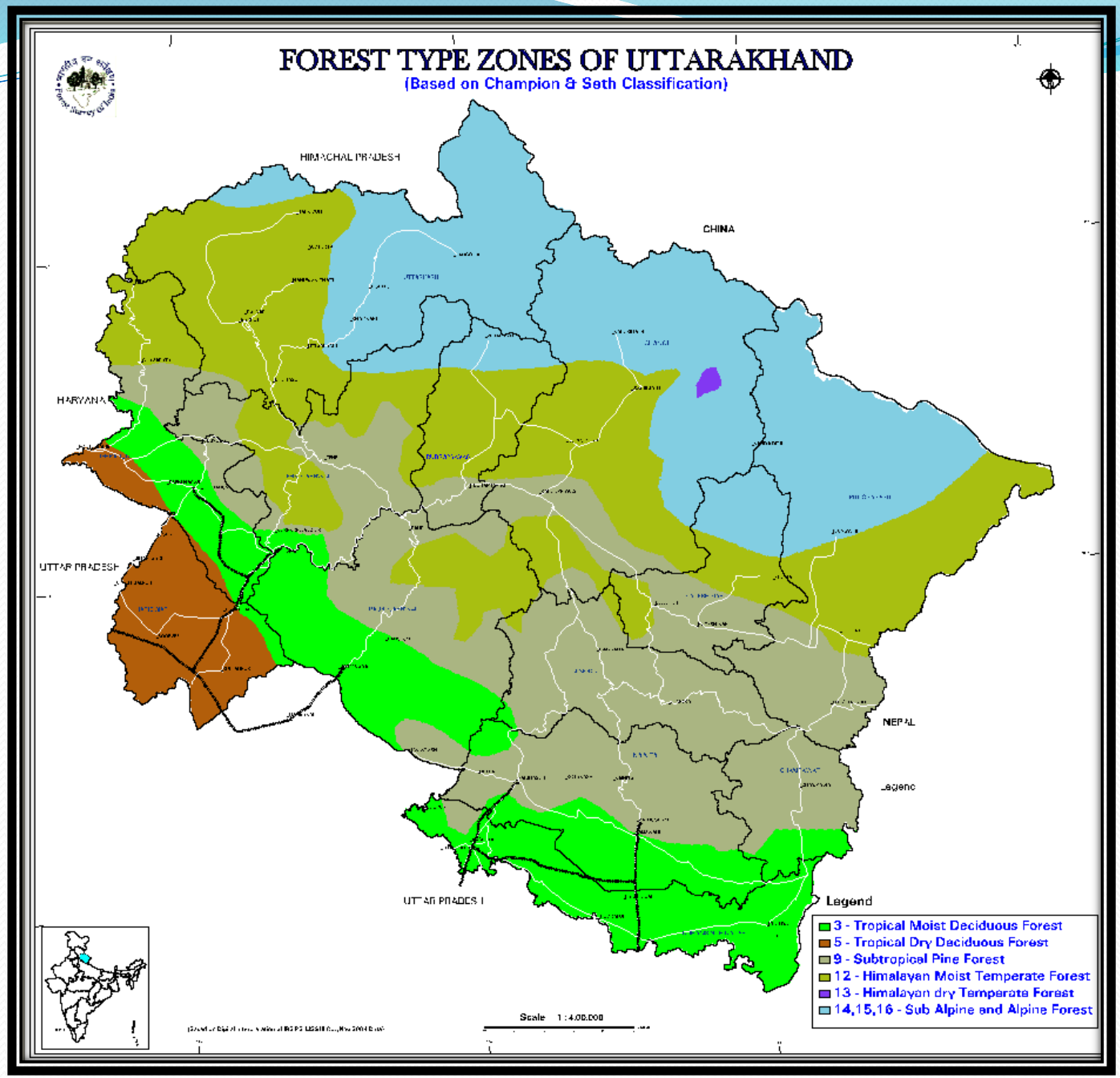
New Biomass Study

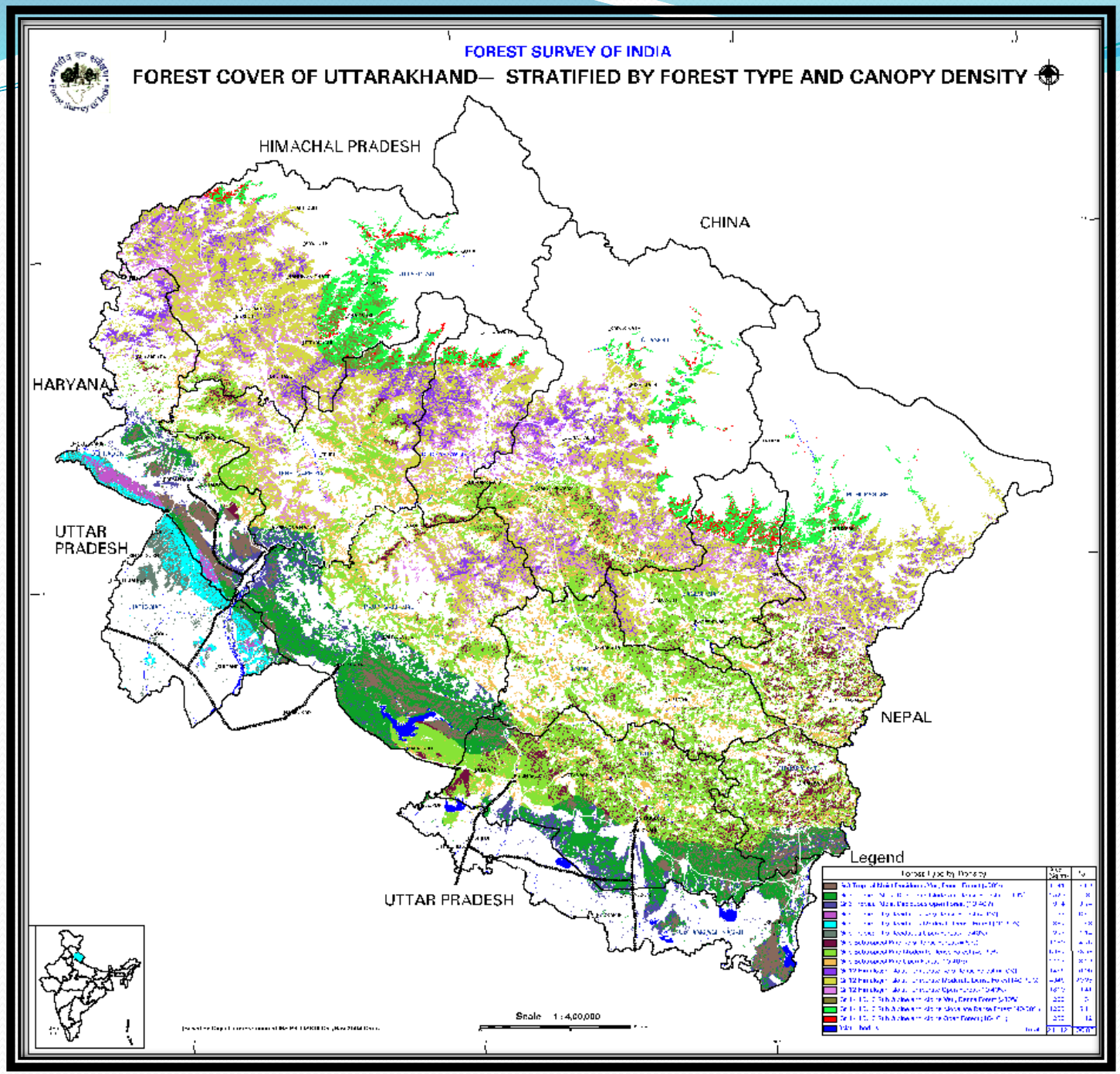
- **FSI launched a new biomass study in August 2008 to measure missing components of forest biomass (not measured by NFI) as per REDD requirement**
- **The study has followed two approaches**
- **(a) measure biomass of herb, shrub, climber, dead wood and litter by laying out sample plots (about 100 plots in each physiographic zone thus in all 1,400 sample plots)**
- **(b) select 20 to 30 number of trees for each species in different zones cut and measure their biomass to generate biomass equations for:**

  i) Dbh of NFI trees Vs. biomass of branch for trees above 10 cm dbh.

  ii) dbh/collar dia Vs. total biomass of trees below 10 cm dbh.

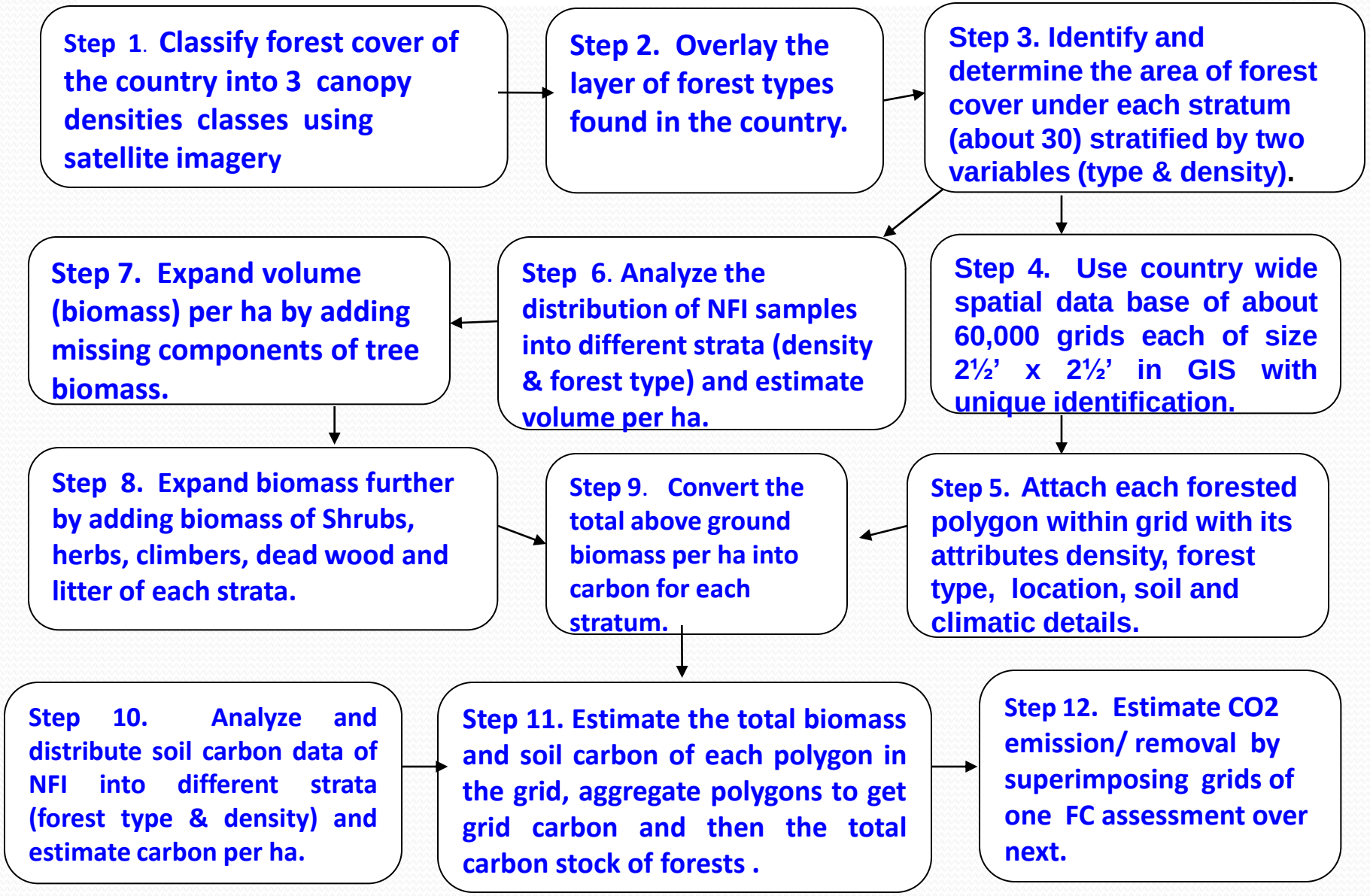

FOREST COVER MAP OF UTTARAKHAND
(Based on Digital Interpretation of IRS IC/ID LISS-III Oct/Nov 2002 Data)
HIMACHAL PRADESH
CHINA
HARYANA
UTTAR PRADESH
NEPAL
UTTAR PRADESH
LEGEND
VERY DENSE FOREST
MODERATELY DENSE FOREST
OPEN FOREST
SCRUB
WATER BODIES
NON FOREST
INTERNATIONAL BOUNDARY
STATE BOUNDARY


FOREST TYPE ZONES OF UTTARAKHAND
(Based on Champion & Seth Classification)
HIMACHAL PRADESH
CHINA
HARYANA
UTTAR PRADESH
NEPAL
UTTAR PRADESH
Legend
3 - Tropical Moist Deciduous Forest
5 - Tropical Dry Deciduous Forest
9 - Subtropical Pine Forest
12 - Himalayan Moist Temperate Forest
13 - Himalayan dry Temperate Forest
14,15,16 - Sub Alpine and Alpine Forest
Scale 1:4,00,000


FOREST SURVEY OF INDIA
FOREST COVER OF UTTARAKHAND— STRATIFIED BY FOREST TYPE AND CANOPY DENSITY
HIMACHAL PRADESH
CHINA
HARYANA
UTTAR PRADESH
NEPAL
UTTAR PRADESH
Legend
Scale 1 : 4,00,000

Forest Type by Density	Area (Sqkm)	%
Gr3 Tropical Moist Deciduous Very Dense Forest (>70%)	1141	4.67
Gr 3 Tropical Moist Deciduous Moderate Dense Forest (40-70%)	2520	10.31
Gr 3 Tropical Moist Deciduous Open Forest (10-40%)	914	3.74
Gr 5 Tropical Dry Deciduous Very Dense Forest (>70%)	133	0.54
Gr 5 Tropical Dry Deciduous Moderate Dense Forest (40-70%)	387	1.58
Gr 5 Tropical Dry Deciduous Open Forest (10-40%)	278	1.14
Gr 9 Subtropical Pine Very Dense Forest (>70%)	1160	4.75
Gr 9 Subtropical Pine Moderate Dense Forest (40-70%)	5757	23.55
Gr 9 Subtropical Pine Open Forest (10-40%)	2118	8.67
Gr 12 Himalayan Moist Temperate Very Dense Forest (>70%)	1489	6.09
Gr 12 Himalayan Moist Temperate Moderate Dense Forest (40-70%)	4949	20.25
Gr 12 Himalayan Moist Temperate Open Forest (10-40%)	1810	7.41
Gr 14,15,16 Sub Alpine and Alpine Very Dense Forest (>70%)	255	1.04
Gr 14,15,16 Sub Alpine and Alpine Moderate Dense Forest (40-70%)	1257	5.14
Gr 14,15,16 Sub Alpine and Alpine Open Forest (10-40%)	275	1.12
Water bodies Total	24442	100.00

Schematic diagram of Estimation of Carbon stock change in India's Forests



Carbon stock of India's forests as in 2007
Table 1

Components	Biomass (mn tons)	Carbon (mn tons)
A. Above Grounds		
A1. Woody biomass of tress above 10 cm dbh (includes stem upto 10 cm dia and branches upto 5 cm dia) from **NFI**	3400	1562
A2. Woody Biomass of the trees above 10 cm dbh (includes stem part less than 10 cm dia and branch part less than 5 cm)	648	298
A3. Woody biomass of tress below 10 cm dbh (includes complete stems as well as branches)	448	206
A4. Biomass of foliage of trees above 10 cm dbh (includes leaves, green twigs, fruits and flowers)	19	9
A5. Biomass of foliage of trees below 10 cm dbh (includes leaves, green twigs, fruits and flowers)	34	16
A6. Biomass of shrubs/herb/climbers	235	82
A. Total above ground	**4785**	**2173**

Carbon stock of India's forests as in 2007
Table 2

B. Below ground	1509	685
T1. Total live biomass (A+B)	6294	2859
C. Deadwood	31	14
D. Litter	385	162
T2. Total dead biomass (C+D)	461	176
E. Soil Organic Carbon	-	4292
Grand total (T1+T2+E)	6709	7328

Capacity building and regional cooperation

- There are several non-annex-I countries whose capacity to monitor the forest cover and forest carbon stock is very weak.
- Besides lack of trained technical staff there is also lack of dedicated institution in the countries.
- Establishment of a monitoring system requires a coordinated approach at the international and regional levels and also cost.
- Regional cooperation could enhance the sharing and exchange of data especially on biomass expansion factors, allometric equations and methodology.


THANKS