NATIONAL FOREST INVENTORY IN INDIA

Workshop on “Monitoring of reduction of emissions from forest degradation”

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Forests constitute a very important natural resource for India.

It is a major land-use and occupy about 23% land area of the country (77 mn ha) but the actual forest cover is only about 20.60% (67.7 mn ha).

India’s population being more than a 1 billion, the per capita forest is too low (600 m2) against world’s average of 6000 m2.

The pressure on forests is therefore high also because more than 70% India’s population has rural based economy.

Trees outside forest (TOF) has become the most potential source for production of wood contributing to more than 80% of the timber at present.
# Two decades of Forest Cover Assessment in India

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Year of Assessment</th>
<th>Satellite &amp; Sensor</th>
<th>Resolution</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1987</td>
<td>LANDSAT MSS</td>
<td>80m x 80m</td>
<td>1:1 million</td>
</tr>
<tr>
<td>II</td>
<td>1989</td>
<td>LANDSAT TM</td>
<td>30m x 30m</td>
<td>1:250,000</td>
</tr>
<tr>
<td>III</td>
<td>1991</td>
<td>IRS-1B LISS-II</td>
<td>36m x 36m</td>
<td>1:50,000</td>
</tr>
<tr>
<td>IV</td>
<td>1993</td>
<td>IRS-1C LISS-III</td>
<td>23m x 23m</td>
<td>1:50,000</td>
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<tr>
<td>V</td>
<td>1995</td>
<td>IRS-1B LISS-II</td>
<td>23m x 23m</td>
<td>1:50,000</td>
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<tr>
<td>VI</td>
<td>1997</td>
<td>IRS-1C/1D LISS-III</td>
<td>23m x 23m</td>
<td>1:50,000</td>
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<tr>
<td>VII</td>
<td>1999</td>
<td>IRS-1D, LISS-III</td>
<td>23m x 23m</td>
<td>1:50,000</td>
</tr>
<tr>
<td>VIII</td>
<td>2001</td>
<td>IRS-P6, LISS-III</td>
<td>23m x 23m</td>
<td>1:50,000</td>
</tr>
<tr>
<td>IX</td>
<td>2003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class</td>
<td>Area (km²)</td>
<td>% of Geo. Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------</td>
<td>----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest Cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Very Dense Forest (more than 70% density)</td>
<td>54,569</td>
<td>1.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Moderately Dense Forest (40% to 70% density)</td>
<td>332,647</td>
<td>10.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Open Forest (10% to 40% density)</td>
<td>289,872</td>
<td>8.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Forest Cover</td>
<td>677,088</td>
<td>20.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-forest Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scrub</td>
<td>38,475</td>
<td>1.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-forest</td>
<td>2,571,700</td>
<td>78.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Geographic Area</td>
<td>3,287,263</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Change in Forest Cover

<table>
<thead>
<tr>
<th></th>
<th>2003 Assessment</th>
<th>2005 Assessment</th>
<th>Change +/-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Dense Forests</td>
<td>54,518</td>
<td>54,569</td>
<td>51</td>
</tr>
<tr>
<td>Moderately Dense Forests</td>
<td>334,056</td>
<td>332,647</td>
<td>-1,409</td>
</tr>
<tr>
<td>Open Forests</td>
<td>289,242</td>
<td>289,872</td>
<td>630</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>677,816</strong></td>
<td><strong>677,088</strong></td>
<td><strong>-728</strong></td>
</tr>
</tbody>
</table>
Submergence of Forest Area in Harda, East Nimar & Dewas Districts
Shifting Cultivation

Improvement

2003

2005

Degradation

2003

2005
History of Forest Inventory in India

• With the start of scientific management of forests in India in 1863 field inventory on a systematic basis started for the preparation of the “Working Plans” at the divisional level.

• This was extended to almost entire forest area of the country and is continuing even today. But the inventories were for limited forest area of a division which was to be worked during next 10-15 years and was for different time frame.

• Further, these inventories were not organised to generate estimates at state/national level for a given time frame.
Field inventory of unexplored forest areas started after the launch of a FAO/UNDP/GOI project named as Pre-Investment Survey of Forest Resources (PISFR) in 1965 which led the foundation of NFI

From 1965 to 1981

- Forest Inventory was confined to project areas for setting up wood based industries
- Sampling design was adopted as per prevailing condition of areas but were based on systematic sampling

Since 1981 NFI was launched with the creation of the FSI

- The country was divided into grids of $2.\frac{1}{2}' \times 2.\frac{1}{2}'$ and Systematic sampling was followed by taking two plots of 0.1 ha in each grid.
- Each year only selected districts were covered due to limitation of manpower and reports were produced
- About 3/4th of the country’s forests were inventoried in 20 years but no reliable estimate at national level of growing stock could be generated.
The basic goal is to estimate growing stock of forests and TOF on a two year basis and improve the estimate in subsequent cycles. However, all the districts of the entire country will be covered in 20 years.

For this purpose, the country has been stratified into 14 physiographic zones.

Ten percent (60) districts are covered in every two year cycle.

The districts are selected randomly within each zone with probability proportion to size.

Along with the Forest inventory, vegetation survey of herbs and shrubs is also carried out.

Measurement of soil and litter carbon is also carried out.
Revised Methodology of NFI--contd
Physiographic Zone Map of India
Revised Methodology of NFI--contd
Physiographic Zones on Forest Cover
Revised Methodology of NFI--contd
Randomly Selected 60 districts
Revised Methodology of NFI --contd

• Topographic sheets of 1:50,000 scale forms the base map for the inventory.

• Firstly, the topographic is divided into grids of 2 ½’ × 2 ½ ’.

• Within each such grid, four sub grids of size 1 ¼ ’ × 1 ¼ ’ are laid.

• Two sub grid are then randomly selected.

• Sample plots are then laid in each sub-grid at the intersection of the diagonals.
TWO SAMPLE PLOTS ARE SELECTED BY TAKING CENTER OF 1¼’X 1¼’ GRID
Topographic sheets on scale 1:50,000 (15'×15' Grid)
Out of four $1\frac{1}{4}' \times 1\frac{1}{4}'$ grids made from $2\frac{1}{2}' \times 2\frac{1}{2}'$ grid only **TWO SAMPLE PLOTS** are selected at the grid centres of $1\frac{1}{4}' \times 1\frac{1}{4}'$
Revised Methodology of NFI -- contd

• At grid centre a square plot of 0.1 ha is laid out

• Measurement of various parameters like dbh, species name, crown-diameter etc. for all trees above 10 cm dbh are carried out.

• For litter and humus and soil carbon, two sub-plots of 1 sq. m are laid out on opposite corners of the inventory plot (0.1 ha).

• Samples of litter and humus and soil are then collected from all the sub-plots.
Laying out of the main sample plot

Plot Size 0.1 ha
Revised Methodology of NFI--contd

• Further, from the centre of the plot measurements are done along the diagonals in all the 4 directions and points are marked at a distance of 30 meters

• Nested quadrats of $3m \times 3m$ for shrubs and $1m \times 1m$ for herbs are then laid out. Regeneration Survey is also carried out in $3m \times 3m$ plots.

• Besides regeneration status it provides information about Plant biodiversity, distribution & abundance.
Nested quadrates with main plot for measuring additional parameters
FSI (Headquarters)
DEHRADUN

Zonal Offices

North Zone
Shimla

East Zone
Kolkata

Central Zone
Nagpur

South Zone
Bangalore
• Data collection, data entry and data checking is done by the four zonal offices located in different part of the country

• Partial data checking, data processing, analysis and output production is done in the headquarters at Dehradun

• More than 250 volume equations developed covering most of the tree species growing in different physiographic zones are used for estimating growing stock.

• The estimated cost of inventory and data processing of a sample plot is about US$ 200.00 per plot of which about US$110.00 is spent on travel to sample plot, field measurement including checking by supervisors and the rest on field preparation, equipment, designing, data entry, processing etc
Measuring forest degradation

• Since NFI is carried out in India since 1981, many districts have been revisited by now.

• Inventory results are available for measuring the broad degradation status (growing stock, no. of tree stems and tree species) of the revisited districts between the two periods.
### Comparison of two time inventory results of selected districts

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>District</th>
<th>Year of Inventory</th>
<th>Veg. Area (km²)</th>
<th>Crop Comp.( tree species)</th>
<th>Vol/ha (m³)</th>
<th>Stems/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>West Kameng (Arunachal Pradesh)</td>
<td>1982 - 83</td>
<td>2,427</td>
<td>Broad Leaves (75%), Pine (25%)</td>
<td>143</td>
<td>208</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005 - 06</td>
<td>3,411</td>
<td>Misc. (38%), Oak (25%), Upland HW (23%), Pine (9%), Bamboo (5%)</td>
<td>118</td>
<td>266</td>
</tr>
<tr>
<td>2</td>
<td>Bijnore (Uttar Pradesh)</td>
<td>1981 - 83</td>
<td>493</td>
<td>Misc. (80%), Sal (16%), Teak (4%)</td>
<td>85</td>
<td>261</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003 - 04</td>
<td>401</td>
<td>Misc. (47%), Khair (17%), Sal (14%), Teak (11%), Lowland HW (11%)</td>
<td>99</td>
<td>316</td>
</tr>
<tr>
<td>3</td>
<td>Jhabua (Madhya Pradesh)</td>
<td>1981 - 82</td>
<td>1,268</td>
<td>Misc. (54%), Teak (38%), Salai (8%)</td>
<td>27</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005 - 06</td>
<td>998</td>
<td>Misc. (54%), Teak +Misc. (29%), Teak (17%)</td>
<td>22</td>
<td>104</td>
</tr>
<tr>
<td>4</td>
<td>Shimoga (Karnataka)</td>
<td>1983 - 84</td>
<td>3,871</td>
<td>WGSE (44%), Deciduous (26%), WGE (22%), Teak (8%)</td>
<td>75</td>
<td>196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003 - 04</td>
<td>2,970</td>
<td>Misc. (64%), LowlandHW (20%), Mixed Bamboo (8%), Teak with misc. (8%)</td>
<td>114</td>
<td>301</td>
</tr>
<tr>
<td>5</td>
<td>West Garo Hills (Meghalaya)</td>
<td>1986 - 88</td>
<td>2,065</td>
<td>Misc. (85%), Sal (11%), Teak (3%)</td>
<td>92</td>
<td>183</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2004 -05</td>
<td>1,093</td>
<td>Misc. (74%), Bamboo (21%), Teak (2%), Sal+Misc. (1%), Mixed Bamboo (1%)</td>
<td>32</td>
<td>142</td>
</tr>
<tr>
<td>6</td>
<td>Thane (Maharastra)</td>
<td>1984 - 85</td>
<td>2,806</td>
<td>Teak (54%), Misc. (46%)</td>
<td>46</td>
<td>189</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2002 - 03</td>
<td>3,165</td>
<td>Teak+Misc. (44%), Misc. (37%), Teak (16%), Lowland HW (2%)</td>
<td>39</td>
<td>26</td>
</tr>
</tbody>
</table>
Inventory of Trees Outside Forests (TOF)

- TOF resource has become most important in today’s context in India as most of timber requirement of industries have to met from TOF.
- In the present methodology, high resolution satellite data (5.8 m) is used to identify TOF patches and stratify the same into:
  - block,
  - linear, and
  - scattered strata
- After the stratification appropriate sample plots are laid on the ground for field inventory.
- On average 4000 sample plots are laid every year.
TREES GROWING IN AGRICULTURAL FIELDS
AILANTHUS EXCELSA & ACACIA NILOTICA ON FARM BUNDS
Casurina in private land
METHODOLOGY FOR ASSESSMENT OF TREE OUTSIDE FOREST USING REMOTE SENSING DATA

- Satellite Data
  - LISS III Data
  - PAN Data
- Geometric and Radiometric Correction & fusion
- Fused Data
- Green wash
- Masking out Green Wash from Fused Data
- Classification of fused data without Green wash
  - Trees in Group
  - Scattered
  - Water Bodies
    - Linear
    - Block
    - Elimination of area < 0.1 ha.
- Green Wash Map
- Digitization of Green wash
- India Map with District boundaries
- Toposheets
- Mosaic
- Field data collection
- Data Analysis & Report Generation
- Classified Map
  - Block
  - Linear
  - Scattered
- Generation of Random Points

Trees in Group
Scattered
Water Bodies
Linear
Block
Elimination of area < 0.1 ha.

Data Analysis & Report Generation

India Map with District boundaries
Toposheets
Mosaic
Green Wash Map
Digitization of Green Wash
Masking out Green Wash from Fused Data
Classification of fused data without Green wash
Green wash
Satellite Data
LISS III Data
PAN Data
Geometric and Radiometric Correction & fusion
Fused Data
Field data collection
Data Analysis & Report Generation

Trees in Group
Scattered
Water Bodies
Linear
Block
Elimination of area < 0.1 ha.

Block
Linear
Scattered
# Plot Size & Number of Samples in rural TOF per district

<table>
<thead>
<tr>
<th>Strata</th>
<th>Plot size</th>
<th>No. of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>0.1 ha</td>
<td>35</td>
</tr>
<tr>
<td>Linear</td>
<td>10x125 m</td>
<td>50</td>
</tr>
<tr>
<td>Scattered</td>
<td>3.0 ha</td>
<td>50</td>
</tr>
<tr>
<td>Scattered (Hill)</td>
<td>0.5 ha</td>
<td>95</td>
</tr>
</tbody>
</table>

- **Random points** for block, linear & scattered stratum along with coordinates communicated to field parties for survey

- Sample points in field are approached by using GPS & data recorded in prescribed formats
• Automatic generation of random points in block, linear and scattered stratum in the TOF area.
• The green wash area (forest) is digitized from the toposheet and is masked out from the merged image.

Then Unsupervised classification is performed

• The classification is done to obtain two classes: TOF area, and water bodies.

• TOF area is further divided into three classes :- Block, Linear & Scattered which are identified according to their geometric shape.
Classified Map

- BLOCK
- LINEAR
- SCATTERED
Field Inventory of Urban TOF

Urban trees have mainly environmental functions-

- In India urban areas are categorized into 5 classes (strata) based on population
- Urban Frame Survey (USF) blocks of National Sample Survey Organization (NSSO) are taken as sampling units by FSI
- Optimum number of UFS blocks are selected in each district for the survey as follows
  
  - If UFS blocks < 500 → 10% selection
  - min 20 blocks
  - UFS blocks > 500 → 5% selection
  - min 50 or max 60 blocks
- Data is collected on the designed formats on various parameters and all trees are measured
Trees Outside Forest Map of Muktsar District
Based on Digital Classification of fused data (IRS 1D LISS-III & PAN)

Legends
- Forest Cover (Masked Out)
- Linear Stratum
- Block Stratum
- Scattered Stratum
- Road
- Railway
- Restricted Area
- Water Bodies
- River Bed
ASSESSMENT OF GROWING STOCK, BIOMASS & CARBON IN INDIA’S FOREST AND TREE OUTSIDE FOREST RESOURCES

ACTIVITIES

Forest Inventory
- Growing Stock
- Number of trees
Vegetation Survey
- Plant diversity indices
- Regeneration survey
- NWFP assessment
Soil Carbon
- Soil carbon
- Carbon in forest floor

Carbon storage in trees

Rural
- Growing Stock
- Number of trees
Carbon storage in TOF rural

Urban
- Growing Stock
- Number of trees
Carbon storage in TOF urban

Methodology for conversion of Growing Stock into Carbon

Growing stock of species \times \text{specific gravity of species} = \text{Biomass}

\text{Biomass} \times \text{carbon percentage (species wise)} = \text{Carbon content}

OUTPUT:
- Estimation of growing stock, biomass of trees within & outside forest
- Carbon stored in trees within & outside forest
- Carbon stored in soil & forest floor
- Regeneration survey
- Assessment of NWFPs
- Assessment of Plant diversity indices
THANKS / Merci

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