THEME 5

Forests and Climate Change
Indian Forestry Congress- 2011
Planning Strategy for REDD+: India

New Delhi, 22 November 2011

Jagdish Kishwan
Additional Director General (Wildlife), MoEF
Former PCCF and HoFF, Jammu and Kashmir
Former DG, ICFRE
also
Member, Core Negotiating Group for UNFCCC
Member, Expert Group on Low Carbon Strategy for Inclusive Growth- Planning Commission

Concept and Philosophy of REDD+

- A national level forest carbon stocks accounting approach
- Any scope for project level actions? Yes for learning and experimentation

India: Implementing COP Decisions on REDD+

- Agreed REDD+ activities contributing to mitigation (para 70 of AWG-LCA)
  - Reducing emissions from deforestation
  - Reducing emissions from forest degradation
  - Conservation of forest carbon stocks
  - Sustainable management of forests
  - Enhancement of forest carbon stocks
### India: Implementing COP Decisions on REDD+

<table>
<thead>
<tr>
<th>National REDD+ framework</th>
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<tbody>
<tr>
<td>National strategy of actions</td>
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<tr>
<td>National forest reference level</td>
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<tr>
<td>National transparent forest monitoring and reporting system</td>
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<tr>
<td>Information system to report on adherence to safeguards</td>
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### National strategy of actions

- Enhancing and improving forest and tree cover (3 Scenarios of investment)
  - NAP (BAU: $1.11 bl Yr⁻¹)
  - NAP+GIM (Accelerated Scenario: $2.13 bl Yr⁻¹)
  - NAP+GIM+Village Forest+Substitution with Wood+Fuel Efficient Wood Stoves (Aggressive Scenario: $4.46 bl Yr⁻¹)
- Carbon service a co-benefit (rather than overarching benefit) in addition to timber, firewood, fodder, fiber, NTFP, water

### National forest reference level

- Based on historical trends of forest carbon stocks
- Embedded with growth trends of population and GDP, and future energy demand
- Open to additional ideas

### Safeguards to be promoted and supported

- Transparent and effective governance
- Rights of indigenous peoples and local communities
- Participation of IPs and LCs
- Conservation of natural forests and biological diversity
  - No conversion of natural forests
  - Reduce displacement of emissions

### Financing options (para 77 of AWG-LCA)

- No tangible progress so far, countries asked to make submissions in Panama

### Indian position

- Favours a flexible combination of market and non-market based mechanisms
- Claim for incentivizing
  - Baseline forest carbon stocks (fund based)
  - Incremental forest carbon stocks (market)
### India: Implementing COP Decisions on REDD+

#### National strategy: Policy aspects
- Safeguard legal and traditional rights of local communities (examples: JFM, CFM, FRA)
- No role for private sector, reiterate
- No specific changes in FM for REDD+
- REDD+ incentives bonus in addition to traditional goods and services to local community from forests
- Policy statement endorsing 100% share of REDD+ to local community and no involvement of private companies
- Participation of local community in assessment and monitoring of forest C stocks
- Capacity building

#### National strategy: Technological aspects
- **Estimation**
  - Move towards more precise estimates
  - Biome and other foreign models good as stopgap arrangement
  - Improve and fine-tune existing methodologies for assessment of forest carbon stocks both biomass and SOC. Use these methodologies for testing and validation of models
  - Use background and knowledge of methodologies to develop indigenous models
Forests and climate change

1. Deforestation and land use change contribute to CO₂ emissions
   - IPCC; 20% of CO₂ emissions
2. Forests provide a large potential to mitigate climate change; REDD, A&R, Bioenergy...
   - IPCC; 15 – 20% of CO₂ emissions
3. Forests will be impacted by climate change and are highly vulnerable to climate impacts
   - Need for adaptation to enable forests to cope with climate change
4. CC could impact Carbon sinks, REDD potential

Forest sector is critical in addressing climate change
Forest sector is very contentious in global negotiations

Issues in Climate Change and Forests

1. GHG Inventory from Forestry or LULUCF sector
   - IPCC methods; data and models
2. Mitigation potential assessments at different levels – for land based projects
   1. CDM, REDD+, Forest conservation, A&R, etc
   2. Barriers and policy options to promote mitigation actions
3. Impact of climate change on forest ecosystems, biodiversity and livelihoods
4. Adaptation and resilience enhancement; practices
5. CDM and REDD+; policy and methodological issues
6. International negotiations – India’s position
7. Greening India Mission – Information/Data needs
Greening India Mission (GIM)

The Mission aims at addressing climate change by

1. Enhancing carbon sinks in sustainably managed forests and other ecosystems
2. Enhancing the resilience and ability of vulnerable species/ ecosystems to adapt to the changing climate
3. Enabling adaptation of forest-dependant local communities in the face of climatic variability.

The door to 2°C is closing, but will we be “locked-in”? IEA, 2011

Without further action, by 2017 all CO2 emissions permitted in the 450 Scenario will be “locked-in” by existing power plants, factories, buildings, etc.

2°C threshold - Projected temperature rise for A1B & A1F1 scenarios

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2°C threshold - Projected temperature rise for A1B & A1F1 scenarios
Failure to migrate: lack of tree range expansion in response to climate change, by Kai Zhu, Christopher W. Woodall, James S. Clark, *Global Change Biology, 2011*

**Abstract**

Tree species are expected to track warming climate by shifting their ranges to higher latitudes or elevations, but current evidence of latitudinal range shifts for suites of species is largely indirect. In response to global warming, offspring of trees are predicted to have ranges extend beyond adults at leading edges and the opposite relationship at trailing edges. Large-scale forest inventory data provide an opportunity to compare present latitudes of seedlings and adult trees at their range limits. Using the USDA Forest Service’s Forest Inventory and Analysis data, we directly compared seedling and tree 5th and 95th percentile latitudes for 92 species in 30 longitudinal bands for 43,334 plots across the eastern United States. We further compared these latitudes with 20th century temperature and precipitation change and functional traits, including seed size and seed spread rate.

Results suggest that 58.7% of the tree species examined show the pattern expected for a population undergoing range contraction, rather than expansion, at both northern and southern boundaries. Fewer species show a pattern consistent with a northward shift (20.7%) and fewer still with a southward shift (16.3%). Only 4.3% are consistent with expansion at both range limits. When compared with the 20th century climate changes that have occurred at the range boundaries themselves, there is no consistent evidence that population spread is greatest in areas where climate has changed most; nor are patterns related to seed size or dispersal characteristics. The fact that the majority of seedling extreme latitudes are less than those for adult trees may emphasize the lack of evidence for climate-mediated migration, and should increase concerns for the risks posed by climate change.
1. 1996 Revised IPCC Guidelines for GHG Inventory of LUCF sector – NATCOM-I
2. Good Practice Guidance for LULUCF Sector IPCC 2003 - NATCOM-II
3. IPCC- GHG Inventory guidelines, 2006
   • AFOLU – Agriculture, Forest and Other land use Sectors

Limitations of Data on Area, Biomass and Carbon Stock
- No periodic forest inventory studies in India
- Land use change matrix for 6 land categories not available
- Carbon pools data not available for different land categories; stocks and changes
- Wood extraction; commercial timber and fuelwood extraction data not available
- No data on forest degradation

Mitigation Options
- Forest Conservation
  – Halting or reducing Deforestation
  – Reducing forest degradation
- Afforestation / Reforestation
- Agro-forestry
- Bio-energy plantations

GHG emissions from LULUCF sector for India (Gg) during 2000

<table>
<thead>
<tr>
<th>Land category</th>
<th>Sub-category</th>
<th>Annual CO2 emissions/removals</th>
<th>CH4</th>
<th>N2O</th>
<th>Total CO2 eq Emissions</th>
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</thead>
<tbody>
<tr>
<td>Forest land</td>
<td>Forest land remaining forest land</td>
<td>-79,918.80</td>
<td>11,600</td>
<td>2,090</td>
<td>-66,228</td>
</tr>
<tr>
<td></td>
<td>Land converted to forest land</td>
<td>-137,475.00</td>
<td></td>
<td></td>
<td>-137,475</td>
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<tr>
<td>Cropland</td>
<td>Crop land remaining crop land</td>
<td>-15,318.44</td>
<td></td>
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<td>-15,318</td>
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<td></td>
<td>Land converted to crop land</td>
<td>-8.87</td>
<td></td>
<td></td>
<td>-8</td>
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<tr>
<td>Grassland</td>
<td>Grassland remaining Grassland</td>
<td>-3,460.77</td>
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<td>-3,460</td>
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<tr>
<td>Settlement</td>
<td>Settlement remaining Settlement</td>
<td>-73.13</td>
<td></td>
<td></td>
<td>-73</td>
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<td></td>
<td>Land converted to Settlement</td>
<td>-2.42</td>
<td></td>
<td></td>
<td>-2.42</td>
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<tr>
<td>Total</td>
<td></td>
<td>-236,257.43</td>
<td>11,600</td>
<td>2,090</td>
<td>-222,567.43</td>
</tr>
</tbody>
</table>

GHG-INVETORY GUIDELINES

1. 1996 Revised IPCC Guidelines for GHG Inventory of LUCF sector – NATCOM-I
2. Good Practice Guidance for LULUCF Sector IPCC 2003 - NATCOM-II
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Mitigation assessment
- CDM projects
- Greening mission
- CAMPA
- JFM / CFM / Social Forestry / NEAB
- REDD plus
- IPCC assessments

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Forests and Climate change

Models for mitigation assessment

- PROCOMAP
- GCOMAP
- CATIE
- TARAM

Assessment of mitigation potential under changing climate

- Climate change will impact forest ecosystems, dominant species and net primary productivity
- Need to assess the impact of climate change on mitigation potential and forest carbon sink
  - Will forests become source from sink
  - What happens to REDD+ potential?

Impact of Climate Change on forest ecosystems and Adaptation Needs
Impact of Climate Change on Indian Forests

Global Vegetation Model:
1. BIOME4: Equilibrium model
2. IBIS (Integrated Biosphere Simulator): dynamic global Vegetation Model
3. Working currently on LPJ & CLM models

Climate Model: GCM and RCM data from
• Hadley HadRM3 data (50x50 km²)
• In future other GCMs will be used

Vulnerability Index and Profile Development
Applicable and necessary for Greening India Mission

<table>
<thead>
<tr>
<th>State</th>
<th>Number of FSI grids in state</th>
<th>% projected to change by 2035</th>
<th>% projected to change by 2085</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rajasthan</td>
<td>802</td>
<td>61.22</td>
<td>78.18</td>
</tr>
<tr>
<td>Jammu &amp; Kashmir</td>
<td>910</td>
<td>57.03</td>
<td>88.35</td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td>3292</td>
<td>48.00</td>
<td>75.85</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>838</td>
<td>47.49</td>
<td>65.39</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>2388</td>
<td>39.20</td>
<td>51.57</td>
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<tr>
<td>Karnataka</td>
<td>1947</td>
<td>38.37</td>
<td>62.20</td>
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<tr>
<td>Tamil Nadu</td>
<td>776</td>
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<tr>
<td>Madhya Pradesh</td>
<td>4432</td>
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<td>48.17</td>
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<td>Maharashtra</td>
<td>2197</td>
<td>21.03</td>
<td>45.33</td>
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<tr>
<td>Uttarakhand</td>
<td>1203</td>
<td>19.04</td>
<td>31.92</td>
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<tr>
<td>Arunachal Pradesh</td>
<td>2666</td>
<td>12.27</td>
<td>6.90</td>
</tr>
<tr>
<td>Orissa</td>
<td>2564</td>
<td>9.71</td>
<td>13.53</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>829</td>
<td>7.96</td>
<td>0.00</td>
</tr>
<tr>
<td>Assam</td>
<td>1261</td>
<td>5.23</td>
<td>1.11</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>1148</td>
<td>0.00</td>
<td>24.30</td>
</tr>
</tbody>
</table>
Forests and Climate change

Initiate long term monitoring studies vegetation response to CC

Enhancing modeling capacity

Generate database for forestry CC related analysis and projects

Conduct regional level; impact and mitigation studies

Developing pilot adaptation project

Addressing Data / Modeling GAPS is most critical for research in the forest sector

Criteria & Indicators for Mitigation projects

- **Disturbance index**: An indication of the human disturbance for a particular forest patch. More the disturbance index, higher the forest vulnerability.
- **Fragmentation status**: An indication of how fragmented the forest patch is. More the fragmentation status, higher the forest vulnerability.
- **Biological richness**: Indicates the species diversity of the forest patch, a measure of the number of species of flora and fauna, per unit area. Higher the biological richness, lower the forest vulnerability.
- **Impact of climate change on carbon sinks of forests**: For estimating climate change impacts, IBIS, which is a dynamic global vegetation model, was used.

Major methodological issues under REDD / CDM

1. Estimation of deforestation / degradation rates; past, current and projections; spatial and temporal estimates – high accuracy
2. Carbon stock change assessment – REDD
3. Data on biomass & SOC growth rates for different species & forest and plantation types
4. Estimation of emissions from deforestation and degradation
5. Baselines/Issue of setting Reference Emissions Levels
6. Drivers of deforestation and degradation
7. Carbon leakage estimation
8. REDD Monitoring and Verification (MRV)

Why Adaptation? When uncertainty in Impact Assessment

- Impacts will be irreversible; e.g.,
  - loss of biodiversity
- Inertia in response to changing climate
- Long gestation period in developing & implementation of adaptation practices
- **Waiting for full knowledge – high risk**
- Large ecological, economic and social implications
  Focus on “win – win” adaptation options

Vulnerability Assessment - Indicators

1. Climate change impact Indicators
2. Bio-physical Indicators
3. Socio-economic Indicators

REDD & CDM

- REDD+ and CDM are likely to become important mechanisms in forestry
- Large opportunities for carbon revenue
- Policy, institutional and financial issues
- Requires rigorous methods for estimating area changes, carbon stock changes
- Requires rigorous monitoring, reporting and verification
- Requires equitable sharing of carbon revenue with local communities

Research

- Initiate long term monitoring studies
- vegetation response to CC
- Enhancing modeling capacity
- Generate database for forestry CC related analysis and projects
- Conduct regional level; impact and mitigation studies
- Developing pilot adaptation project

Addressing Data / Modeling GAPS is most critical for research in the forest sector
# National Mission for a Green India

*Under the National Action Plan on Climate Change*

## 22nd Nov, 2011

### What is at Stake?

![Forest Cover Map of India](image)

### Making of Mission for Green India: Trying to develop an Inclusive approach

**Public Inputs in planning (2010-11)**
- Draft document on [website](#) 23rd May 2010, in 11 languages
- 7 Regional Consultations; Over 1450 people; Thousands of mails received
- Revised draft on website in Oct 2010
- Deliberations in PM Council & Endorsement of Mission on 22nd Feb; outlay of 200 crores for Prep Year; with IMG

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Forests and Climate change

Delineating priority landscapes using value of forest cover, corridor, BPL and ST population

A total of 294 villages in 5 clusters are given very high priority (Red)

The Reform Agenda and Demand Driven

- **Reform Agenda as conditionality**
  - Strengthen Decentralized forest governance ,
  - Centrality of Gram Sabha for improved forest governance; poly centric and nested organisations
  - Second Generation reform in JFM
  - Revamped FDAs
  - Filling of vacancies of frontline staff
  - Easing out of regulatory framework on felling and transit of timber

**Mission Details**

A. **Mission Aim**

Respond to climate change by a combination of adaptation and mitigation measures, which would help :

- Enhancing carbon sinks in sustainably managed forests and other ecosystems;
- Adaptation of vulnerable species/ecosystems to the changing climate; and
- Adaptation of forest-dependent communities.

B. **Mission Objectives**

1. Increased forest/tree cover on 5 m ha of forest/non-forest lands and improved quality of forest cover on another 5 m ha (a total of 10 m ha)
2. Improved ecosystem services including biodiversity, hydrological services and carbon sequestration as a result of treatment of 10 m ha (measurements?)
3. Increased forest-based livelihood income for 3 million forest dependent households
4. Enhanced annual CO2 sequestration of 50-60 million tonnes by the year 2022

C. **Mission Outputs**: 5mn ha quality improvement and 5mn ha new forest cover

1. Qualitative improvement of forest cover/ ecosystems in:
   - 1.5 m ha dense forests
   - 3.0 m ha of degraded forests
   - 0.4 m ha of grasslands
   - 0.1 m ha of wetlands
2. Creating new forest cover through eco-restoration/afforestation
   - 1.8 m ha of scrub, mangroves, ravines, cold desert, shifting cultivation areas, abandoned mining area
   - 0.2 m ha of urban peri urban
   - 3.0 m ha of agro/social forestry: no cultivable land
3. Improved livelihoods for about 3 million households
4. Community institutions manage forests under the Mission
5. Project area households adopt fuel wood efficiency and alternative RE devices

5 sub Missions and Cross cutting interventions

**Mission Details**

- **Business as Unusual**: Key Innovations
  - Improvement in forests – both qualitative and quantitative (5mha+5mha)
  - Focus on a range of ecosystem services
    - Emphasis on biodiversity, water and improved biomass; Carbon sequestration as co-benefit
  - Adoption of Landscape-based Approach
    - Landscape prioritisation to use a range of criteria
    - Interventions at "scale" (5000-6000 hectares) at a time;
    - Ecosystems including forests, grasslands, wetlands, cold desert, ravines, Jhum, abandoned mining areas, urban and peri-urban, agro ecosystem etc
    - Simultaneous treatment of forest and non forest areas
    - Addressing key drivers of degradation; convergence principle
    - Capacities/ leadership to manage landscape level

  Countries now shifting towards landscape approach for multiple values,
### Mission Details

#### F. Mission Monitoring Framework

- **Improved monitoring at Outcome Level:**
  - Monitoring at 4 levels:
    - Self-monitoring by community and field staff (appropriator or resource consumer are best placed to monitor)
    - “Eye in the Sky” + GIS (geomatic)
    - Monitoring by third party
    - Monitoring key indicators (long term)
- **Social Audit (learning from MNREGA)**
- **Auditing by CAG/AG**

### Mission Details

#### Budget & Timeframe

- **Total Mission Cost Rs 46,000 crore over 10 years (Rs. 34,000 cr + Rs. 12,000 cr), covering both Centre and States**
- **Mission to run 2011-2022**
  - Mission implementation to coincide with 12th and 13th Five year Plan
  - Year 1 (2011-2012) to be preparatory year
- **The Mission document to lead to formulation of State Action Plans and Plan at local levels**

### GIM document: Inputs from the PM Council on climate change

- Full range of ES service benefits to be computed, not just carbon
- Must address regulatory regime on farmers lands
- Caveat on agro forestry
- Linkages with the MNRES
- Unlocking of the CAMPA

### Preparatory phase: Key Processes & Outputs

- **Operational guidelines: also revised GIM doc**
- **Institutional & Procedural**
  - National: (Core Staff; Governing Council; Autonomous Society)
  - State: Strengthening of SFDA
  - MoEF processes: Cabinet note, EFC, IMG proposal, Consultant team
- **Plans:**
  - State: One year bridge plan; State Perspective Plan (5-10 years)
- **Local Plan implementation:** Institutions; livelihood support; early nursery preps etc
- **Communication & Awareness**
- **Research Studies /Assessments**

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**Positioning Green India Mission Phase I (2012-2014)**

- National Afforestation Programme (in non-GIM areas)
- Forestry / Greening Programs
- CAMPA
- State APOs
- Convergence (e.g., MNREGA, IWMP etc.)
- Green India Mission (predominantly in identified landscapes)
- Thirteenth Finance Commission

**Banking on Forests: Kanchi Kohli and Manju Menon**

- GIM is carbon complaint; new forest are carbon stocks
- Will GIM really put meaning into participatory forestry or just another rhetoric
- Afforestation will continue to create problem of access for poor
- Where are the commons, particularly wastelands
- De-greening not addressed
- CAMPA and REDD funding

**Engendering the climate for Change: Aditi Kapoor**

- Weak gender focus; limited role for women in forest management foreseen; Mission meant for afforestation and Carbon
Making of Mission for Green India: An Inclusive Approach

Activities in 2011-12

- Activity calendar/Road Map discussed during March Consultation
- April 26th Consultations
- NAEB to anchor the Mission in the preparatory year
- Mail Groups Set up to put up guidelines
- Note for IMG prepared
- Cabinet note prepared and circulated
- IA drafted
- Regional Consultations for selection of landscapes
- Review of progress by PMO and Cab Sect

We are we in the preparatory year

- Limited progress
- Key issues:
  - process guidelines
  - Procedural
  - Institutional issues
  - Financing the GIM

Remembering Robert Frost

Wood could be lonely, dark and deep;
  But we have the promises to keep
Miles to go before we sleep...
Understanding present and future carbon cycling of forests: Some methodological problems

A. Shvidenko, H. Boettcher
International Institute for Applied Systems Analysis, Laxenburg, A-2361 Austria

Indian Forestry Congress, New Delhi, India, 21-26 November 2011

Two ways of study of carbon cycling

- **Pool based approach:** $\text{NBP} = \Delta \text{LB} + \Delta \text{DW} + \Delta \text{SC}$
  - LB - Live biomass
  - DW - Dead wood (coarse woody debris)
  - SC - Soil carbon, including on-ground organic layer

- **Flux-based approach:** $\text{NBP} = \text{NPP} - \text{HSR} - \text{DEC} - \text{LF} - \text{D}$
  - NPP - Net Primary Production
  - HSR - Heterotrophic soil respiration
  - LF - Lateral fluxes to hydrosphere and lithosphere
  - DEC - Decomposition flux
  - D – Flux caused by Disturbances

International Institute for Applied Systems Analysis (IIASA)

Located in a 18th century castle “Schloss Laxenburg” (Habsburg), 30 minutes south of Vienna; founded in 1972

East-West -> North-South -> Global
Major principle: integration, harmonizing and multiple constraints of independent methods and results

Landscape-ecosystem approach
Process-based and other models
Flux measurements
Multi-sensor remote sensing concept
Inverse modeling

General philosophy: Need of Verified Full Carbon Account (FCA)

Full: ALL (forest) ecosystems, ALL processes, ALL carbon contained substances – spatially distributed and continuous in time

Verified: reliable and comprehensive account of uncertainties for all modules and at all stages of the account, to a possible extent – reliable and comprehensively

Uncertainty is an aggregation of insufficiencies of outputs of the accounting system, regardless of whether those insufficiencies result from a lack of knowledge, intricacy of the system, or other causes

But
FCA is underspecified task (fuzzy, full complexity, or ill-defined problem), which cannot be verified by strict formal methods

Approach: As comprehensive as possible following the principles of applied systems analysis

Landscape-ecosystem approach: an empirical (semi-empirical) background of FCA

- As comprehensive as possible following the requirements of the applied systems analysis
- Relevant combination of flux- and pool-based approaches
- Strict mono-semantic definitions and proper classification schemes; harmonization of these with other approaches
- Explicit intra- and intersystem structuring: optimization of input data; explicit algorithmic form of accounting schemes, models and assumptions
- Spatially and temporally explicit distribution of pools and fluxes
- Correction of many year average estimates for environmental and climatic indicators of individual years
- Assessment of uncertainties at all stages and for all modules of the account – intra-approach uncertainty
- Comparative analysis with independent sources, harmonizing and multiple constraints of the intermediate and final results

Multi-sensor remote sensing concept

- NOAA AVHRR
- MODIS
- GLC-2000
- MODIS-VCF
- LANDSAT TM
- ENVISAT MERIS
- ENVISAT ASAR
- JERS
- ERS-1 and ERS-2
- ALOS PALSAR

Information Background of FCA – Integrated Land Information System of Russia

Multi-layer and multi-scale GIS – a cartographical basis of ILIS
Climatic corrections of major fluxes:
Impact of monthly temperature on NPP

\[ \Delta NPP = F(\Delta T>5^\circ C, \Delta P>5^\circ C, \Delta [CO_2]) \]

\[ \Delta HR = \Phi(\Delta T>0^\circ C, \Delta Tann, \Delta P>5^\circ C, \Delta T>5^\circ C) \]

\[ \Delta HR = \phi(11 \text{ seasonal climatic indicators}) \]

Examples of ILIS layers – carbon pools of forest ecosystems of Russia

- Live biomass (Pg C), 2009
  - Live biomass: 37.5
  - Coarse woody debris: 7.0
  - Litter carbon: 8.3
  - Soil carbon: 136.2
  - Total: 193.4

- Litter

- Total soil carbon

NPP by forest enterprises of Russia: LEA vs MODIS

- MODIS NPP = -105.5381 + 2.6561*x - 0.0048*x^2 + 2.9488E-6*x^3
  (R^2 = 0.46)

Examples of ILIS – Net Primary Production

Net Primary Production (2009) 2.61±0.20 Pg C year⁻¹

Other methods
- DGVMs (ensemble of 17 models, Cramer et al. 1999): +6.3%
- Chlorophyll index by Voronin (Zavarzin 2007): +1.5%
- MODIS: +0.0%
- Different inventories: from -36% to +93%

Examples of ILIS – Background of ILIS (1 km resolution)

Agreement/confidence of sources by classes of the hybrid land cover map (1 & 2 are omitted for clarity)

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- Live biomass (Pg C), 2009
  - Live biomass: 37.5
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  - Litter carbon: 8.3
  - Soil carbon: 136.2
  - Total: 193.4

- Litter

- Total soil carbon

NPP by forest enterprises of Russia: LEA vs MODIS

- MODIS NPP = -105.5381 + 2.6561*x - 0.0048*x^2 + 2.9488E-6*x^3
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Net Primary Production (2009) 2.61±0.20 Pg C year⁻¹

Other methods
- DGVMs (ensemble of 17 models, Cramer et al. 1999): +6.3%
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Forests and Climate change

Heterotrophic soil respiration: Initial data

- Soil map of the Russian Federation 1:2.5 Mio (Fridland, 1988)
- Hybrid land cover (Schepaschenko et al., 2010)
- Database of measurements of organic carbon in soils of Russia (1068 records-Kurganova, Mukhortova, Schepaschenko)
- Global database of soil respiration (3592 records)
- Map of bioclimatic zones (Stolbovovoi, McCallum, 2002)
- Administrative map

Method of estimation of HSR

- Regression models of total soil respiration (SR) on climate by soil types
- Modification of models by region/bioclimatic zone, vegetation type and disturbance
- Model of share of autotrophic respiration in total SR by soil types
- Regression correction of SR by level of Net Primary Production

Modification of SR by regions/bioclimatic zone, vegetation type, land-use and disturbance

\[ C_I = \frac{R_{\text{measured}}}{R_{\text{mod}}} \]

Corrections are made by the ratio between average measured SR \((R_{\text{measured}})\) to SR, calculated by climatic models \((R_{\text{mod}})\) for each region, zone, vegetation type, land-use and disturbance

Heterotrophic soil respiration (g C m\(^{-2}\))

Burnt areas and direct fire emissions in Russia in 1998-2010

- Average area of wildfire in 1998-2010 r.r. is estimated at 8.2 Mio ha and carbon emission 121 T C yr\(^{-1}\)

Full carbon account for Russia in 2009 – flux-based approach

- All ecosystems of Russia in 2000-2010 served as a net carbon sink at 0.5-0.7 Pg per year
- Of this sink, ~90% was provided by forests

Source: Shvidenko et al. 2011

Source: Ciais et al. 2010

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[ 707 ]
Change of carbon stock in boreal ecosystems in 1990-2007: net sink at 0.5 Pg C year\(^{-1}\) or 21% of established forests (Pan et al. 2011)

- Estimates for Eurasia, Pg C year\(^{-1}\)
  - Fan et al., 1999, Science: \(+0.1 \pm 0.7\)
  - Bousquet et al., 1999, JGR: \(-1.8 \pm 1.0\)
  - Rodenback et al., 2003, AChPh: \(+0.2 \pm 0.3\)
  - Gurney et al., 2004, GChB: \(-0.7 \pm 1.0\)

- Estimates for boreal Asia, Pg C year\(^{-1}\)
  - Maksyutov et al., 2003 (1992-1996): \(-0.62 \pm 0.36\)
  - Gurney et al., 2003 (1992-1996): \(-0.58 \pm 0.56\)
  - Baker et al. (1988-2003): \(-0.37 \pm 0.24\)
  - Patra et al., 2006 (1999-2001): \(-0.33 \pm 0.78\)

- Estimates for Russia, Pg C year\(^{-1}\)
  - Ciais et al., 2010 (2000-2005), 4 dif. Inv.: \(-0.65 \pm 0.12\)
  - Shvidenko et al., 2010 (2003-2008), LEA: \(-0.57 \pm 0.26\)

TEM – Terrestrial CO\(_2\) Exchange

Inverse modeling

We should be planning to adapt to at least 3-4°C of global warming

Global average surface temperature scenarios for peak emissions at three different dates with 3%-per-year reductions in greenhouse gas emissions. Source: Parry et al. Nature 458, 30 April 2009

Planning adaptation and mitigation strategies in forestry and forest sector

(1) Again this is a typical case of full complexity [fuzzy, underspecified] problems – ill-defined and quasi-manageable task, i.e.

- Structurally, functionally and dynamically intricate
- Non-separable from context, observation and interest
- Multi-objective/subjective
- Inherently uncertain due to fragmentary knowledge and the lack of any proper validation
Planning adaptation and mitigation strategies in forestry and forest sector

(2) Future is very uncertain and complex
- Climatic projections by AOGCMs are not consistent
- Ecological, social and economic developments are hardly predictable
- Complexity, non-linear responses and feedbacks
- Need to take decisions for dynamic fuzzy system under uncertainty
- Needs to derive minimum mitigation standards from the limits of adaptation
- Relevancy to consider multiple strategies that integrate mitigation and adaptation measures in no-regret and win-win fashion

Planning adaptation and mitigation strategies in forestry and forest sector

(3) Our current knowledge is often not satisfactory
- How much stable is the direct stimulation of photosynthesis and NPP by the environmental change?
- How are terrestrial ecosystems functioning under dynamic conditions of multiple limitations for life resources?
- To what extent do the limitations bound CO2 fertilization effect and how long?
- How much nitrogen deposition is able to eliminate lack of available nitrogen in high latitudes?
- How do all these changes interact with the hydrological cycle, particularly with water stress?
- How will destruction of permafrost impact forest ecosystems of high latitudes?
- What is future governance of environment and natural resources?

Planning adaptation and mitigation strategies

(4) Robust policies – a background of the planning which should:
- Ensure long-term stability of systems against multiple events within the sustainable forest management paradigm;
- Include ecological, economic, and social dimensions;
- Account for extreme events;
- Consider uncertainties in a holistic way;
- Allow for flexibility a diversity of decisions dependent on associated risks and costs;
- Include safety criteria, constraints, and performance indicators of involved agents; and
- Allow to minimize losses if the alternative scenario is realized

Distribution of bioclimatic zone in Northern Asia under current (а) and 2090 climate (model SibClim3, Vygodskaya et al. 2007)

Water (0), tundra (1), forest tundra (2), dark coniferous (3), light coniferous (4), forest steppe (5), steppe (6), desert (7), polar desert (8).

Adaptive forest management: climate change vs management (LDSM Landis – II)

Climate change research at IIASA

Background

- EU climate policy has set emission reduction targets of 20% below 1990 levels in 2020 to be achieved through measures implemented by MS.
- This target does not include LULUCF (land use, including forest management) although EU forests are significant sinks.
- EU climate policy has set renewable energy and biofuel targets for 2020 to be implemented by MS.
- Increased demand for bioenergy from forests can either be met through increased imports or increased domestic wood extraction in the EU.

Research questions

- How long will the current sink of EU forests be maintained in the near future?
- Potential conflict between carbon storage in forests and the increased use of forest bioenergy?
- What is the order of magnitude for a given policy scenario?

Driver: Bioenergy production in EU

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>10,000</td>
<td>20,000</td>
</tr>
<tr>
<td>2010</td>
<td>15,000</td>
<td>25,000</td>
</tr>
<tr>
<td>2020</td>
<td>20,000</td>
<td>30,000</td>
</tr>
<tr>
<td>2030</td>
<td>25,000</td>
<td>35,000</td>
</tr>
</tbody>
</table>

Includes current trends and policies including the recent economic downturn and takes into account bioenergy markets.

Includes the baseline + the Climate and energy package i.e. the renewable target of 20% in 2020 in the EU.
Forests and Climate change

Conclusions

- Forest sink in EU (excl. afforestation) expected to decline by 15% in 2020 and 25-40% in 2030 compared to 2010.
- Drivers are:
  - the demand for wood for energy and material use that is projected to increase further in the future.
  - shifts in the forest structure towards an older forests that lower the strength of forest carbon accumulation.
- Impact on EU forest carbon stocks depends on whether the demand growth will be met by internal production or increased imports – indirect effects.

Results: Baseline development

Forest biomass only. Results calculated by Global Forest Model G4M Developed by IIASA

Results: Impact of increased bioenergy use on EU forest sink

Absolute and relative differences of reference scenario to baseline for harvest volume and forest management CO₂ sink in Mm³ (harvest) and Gg CO₂ (sink).

<table>
<thead>
<tr>
<th>Year</th>
<th>Harvest</th>
<th>Sink G4M</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>5.3</td>
<td>0</td>
</tr>
<tr>
<td>2015</td>
<td>10.5</td>
<td>-4,400</td>
</tr>
<tr>
<td>2020</td>
<td>15.8</td>
<td>-11,600</td>
</tr>
<tr>
<td>2025</td>
<td>4.7</td>
<td>-2,500</td>
</tr>
<tr>
<td>2030</td>
<td>-6.4</td>
<td>16,100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Share of area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-20</td>
</tr>
<tr>
<td>21-40</td>
</tr>
<tr>
<td>41-60</td>
</tr>
<tr>
<td>61-80</td>
</tr>
<tr>
<td>81-100</td>
</tr>
<tr>
<td>101-120</td>
</tr>
<tr>
<td>121-140</td>
</tr>
<tr>
<td>&gt;140</td>
</tr>
</tbody>
</table>

Driver: European forest age class structure

Results: Sensitivity of forestry models.

Mitigation potential of baseline emissions and costs in 2020

Mitigation in Gg CO₂ per year
Thank you!

Hannes Böttcher
IIASA, Austria
bottcher@iiasa.ac.at

The study was financially supported by the European Commission - DG Environment and Climate Action through the tender contract “Analysis of potential and costs of LUC/FC use by EU Member States” contract ref no. 07/2009/541003/BE/001/0001 The research leading to these results has received funding from the European Community’s Framework Programme VII under grant agreement: ADVANCE: ADAPTIVE FORWARD-LOOKING AND VULNERABILITY-CENTRED EU Adaptation Strategies and Managers (call 12). The authors would like to thank Roberto Mill (JRC) for assistance with national data compilation and Geri-Jan Nabuurs (EF) and Michael Obersteiner (IIASA) for comments on the approach and draft versions of the manuscript. We acknowledge the data contribution of several national experts and institutions in particular from the following countries: Belgium, Czech Republic, Finland, Italy, Latvia, and Sweden.
Forests and Climate change

India’s performance since independence

- India reversed deforestation and led its forests into net carbon sink.
- Constitutional changes and FCA played crucial role
- Between 1995 to 2005 C stocks in Indian forests increased from 6245 to 6622 Mt - annual increment of 38 Mt of C or 138 Mt of CO2 enough to neutralize 9.31% of the total of India’s emission of the year 2000.
- Compounded annual growth rate of GHG emissions in CO2e is 4.2% (Kishwan et al., 2009), emissions in 2020 will be 95% higher than in 2000.

“A “large and persistent” carbon sink

- Globally, forests are the single largest agent of mitigation of climate change
- “large and persistent” carbon sink of 2.4 ± 0.4 Gt C/yr averaged over two decades beginning 1990
- This is 27% of the current levels of annual anthropogenic carbon emissions
- Larger than the oceanic intake of about 2.3±0.4 Gt C/year

The Possible Contours of Mitigation and Adaptation in Forestry Sector in India in the Coming Decade

Dr Promode Kant
Greater potential lies in Intensive Forest Management

• We seem to be practising ‘do nothing’ management
• Filing court cases of illegal felling and encroachments
• Rare working of forests, harvesting only dead trees
• Even JFMCs only expected to stop illegal felling
• Very intensive management with high investment not only in plantations but also in natural forests
• Intense Assisted Natural Regeneration and appropriate harvesting for enhanced productivity
• Leading to increased C sequestration and storage both in forests and in harvested products
• And production of biomass based energy

Comparison with China

• Forest cover in 1950 barley 8.5%, rose to 12% in early 1980s and 13.92% in early 1990s.
• Now stands at 18.21% covering 180 Mha of land.
• Over the past two decades an average of four million hectares planted annually.
• Now 54 million hectares of man-made forest with stock volumes of about 1.505 billion m$^3$.
• Total biomass in forests and other wooded lands of China including the deadwood biomass rose from 11883 Mt in 1990 to 14029 Mt in 2000 and 14961 Mt in the year 2005 (FAO 2005).
• Average annual increase was 205 Mt of biomass or about 301 Mt CO$_2$e more than double of India’s 138 Mt CO$_2$e

Is Green India Mission ambitious enough?

• Enhanced annual CO2 sequestration of 50-60 Mt by 2020 offsetting 6 % compared to 4.87 % in the absence of the Mission
• Increase in forest and tree cover would be mostly in agroforestry and SF (3 Mha), shifting cultivation areas, abandoned mining lands, mangroves, ravines (1.8 Mha) and (0.2 Mha) in urban
• Improvement in forest cover over degraded forests (3 Mha) and dense forests (1.5 Mha) grasslands (0.4 Mha) and wetlands (0.1 Mha)
• Annual Outlay of Rs 8,500 cr increased by 4600 cr

GHG emission offsets by forests over the years

• 1990 - 13.98%
• 1994 – 11.25%
• 2000 – 9.31%
• 2010 – 6.53%
• 2020 – 4.87%
• This is not good enough. Much more is possible.

Role of TOF in China

• Increase within forests while biomass in “other wooded lands” (corresponding to TOF in India) decreased from 993 Mt in 1990 to 982 in 2000 and 934 Mt in 2005
• Trend is similar to India where TOF stock came down from 1616 to 1599 Mm$^3$ between 2005 to 2007 though TOF area increased from 2.79 to 2.82 % of geographical area.
• Shorter rotation harvesting in TOF
• Availability of large number of well distributed TOF reduces pressure of demand on public forests
• Ecological demand over TOF is limited – can be harvested as per need – contributes more to CC mitigation
• Greater utilization of TOF biomass implies slower increase in fossil energy consumption when biomass is used as bioenergy or as partial replacement for steel, aluminium, cement that are very energy intensive.

China’s determined use of forests to offset its industrial GHG

• In 2009 China announced plans to reduce emission intensity / unit GDP in 2020 by 40 - 45 % against 2005 levels
• Planting additional 40 Mha and increase the stock volumes by 1.3 billion m$^3$ from 2006 to 2020.
• Can they do it?
• Yin et al (2011) - in a comparable period between 1990 and 2005 China’s forest area increased by 40 Mha and stock by 2.77 billion m$^3$, which is equivalent to 2910 Mt of biomass or 1450 Mt of Carbon or 5321 Mt CO$_2$.
• India’s case is a contrast – more a question of approach and resolve
Forests and Climate change

Economic contribution is a key requirement of sustained political support

- Bigger advantage of this approach is that it creates jobs.
- Nair and Rutt, 2009, - in forestry sector annual expenditure of $ 1 million creates between 500 to 1000 full time jobs
- Highest creation of new full time jobs is in A/R, desertification control, conservation, fire, indigenous forest management, watershed, improvement in productivity of existing planted forests, agro forestry, urban and peri-urban forestry and skill improvement in forestry sector.
- Also in conservation activities like demarcation of boundaries, maintenance of inspection paths and roads and creating and managing nature education centers
- Recreational activities

Possibilities in temperate forests

- Assuming 30 years to grow to next dia class - harvesting possibilities of 543 Mcum in 30 years or 19 Mcum annually.
- Keeping 50% mountain forests inviolate for preserving biodiversity, steep slopes, sensitive ecosystems etc would mean 9.5 Mcum/yr
- This is twice the timber imported by India in 2008 at average price of $274/cum or $2.6 Bn
- 40% additional non-timber biomass usable as fuel

Larger opportunities in tropical and subtropical

- Assuming 20 years to grow from one class to next
- Possibilities of an increase of 2305 Mcum in tropical forests over 20 years or 115 Mcum/yr
- An intensive management system with intense ANR, sustainable harvesting, keeping forests vigorous
- Can natural forests be worked at all?
- Harvesting before 1950s caused little damage
- Damage due to failure in governance and management, not because natural forests are beyond working

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Increased Role of TOF

- TOF critical because it gives enormous flexibility to forest management
- Enhanced agricultural productivity and agri-reforms needed for making marginal agri lands available for tree cultivation
- Up to 10% of least productive agri-lands – 17 Mha - could come under tree without affecting food security
- Making smallholder forestry attractive,
- Rethink on timber transit rules
- PES for smallholders

Significant increase in GHG offset

- possible to have an annual accrual of 134 M cum of commercial wood from the temperate and tropical forests combined which is equivalent to 142 Mt of biomass or 71.1 Mt of Carbon or 261 Mt of CO2e.
- A different strategy for the PAs, steep slopes and Biodiversity rich forests: complete preservation
- Assuming 20% forests (50% in temperate + 10% elsewhere) fall under this category - annual accrual would be 20% less or about 209 Mt CO2e.
- Adding contribution of NGIM it become 269 Mt CO2e/yr – double of present levels

Diameter class-wise stock position in temperate and tropical forests

<table>
<thead>
<tr>
<th>Diameter Class</th>
<th>Temperate</th>
<th>Tropical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stems Millions</td>
<td>Vol Mm³</td>
</tr>
<tr>
<td>10-30 cm</td>
<td>831.65</td>
<td>126.54</td>
</tr>
<tr>
<td>30-50 cm</td>
<td>283.90</td>
<td>426.26</td>
</tr>
<tr>
<td>50+ cm</td>
<td>134.55</td>
<td>218.57</td>
</tr>
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Adaptation

- Ecosystems are expressions of climate and geography, as climate changes ecosystems will exhibit commensurate changes.
- Response of ecosystem constituents – flora and fauna - to these changes would be in accordance with their genetic resilience, phenological plasticity and the possibility and range of mobility.
- Generally speaking the fauna and shorter lived plants may show altitudinal or latitudinal migration.
- Adaptation programme needs to be designed differently from the normal developmental programme.
- It must look at what would be available in greater measures under the changing climate and then convert that into a useful product.
- Simultaneously, it must assess what would be available less as the globe warms up and initiate efforts to conserve the same.

Summarizing Role of Forests in CC Mitigation

Increased C sequestration and storage subject to

- Non-declining welfare over time from the forests
- Non-declining levels of consumption of forest goods and services over time
- Constant or increasing stocks of all forest capital (natural+ plantation+ human) over time with natural capital not dipping below critical levels for any ecosystem

Critical NC

- That NC which, if destroyed, has profoundly damaging consequences
- Difficulty lies in finding which is critical and what is the level beyond which the damage is profound
- Strong sustainability stays far above critical NC whereas weak sustainability must be guarded against crossing threshold
- Market has no inbuilt safeguards – regulatory regime needed

MC enhances the utility of NC

- An important part of SFM is to meet the local forest based needs
- Plantations may give higher levels of satisfaction to the local stakeholders
- If harm to biodiversity is not serious and irreversible then a good proportion of MC might actually be in the interest of SFM
- Leaving a good stock of commercial timber for next generation might serve the purpose of SFM over a larger area
- Over a longer term, and managed judiciously, plantations permit natural ecosystems to replace them

Sustainable Forest Management

- Keeping forest capital stock and productivity intact over succeeding generations
- But capital stock is not natural forests alone
- Total Forest Capital (TFC)= Natural forest capital (NC)+ Man made forest capital (MC)+ Forest related Institutional capital (IC)
- SFM should be seen as keeping intergeneration TFC intact with NC not falling below \( N_{C_{\text{critical}}} \)
- Institutional capital is high in India, capable of recreating forests given adequate support

MC enhances the utility of NC

- Bequeathing next generation zero MC may be as unwise as bequeathing zero NC
- If a particular NC is abundant a part of it substituted by MC can actually complement NC because together they provide higher satisfaction to society
- And if scarce then conserving more NC will bring greater satisfaction

Critical NC

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Adaptation

- early days yet for adaptation - not yet clear what would be the likely changes and what the adaptation measures should try to achieve in the immediate, medium and long term.
- Best use of funds in the short term may be for skill enhancement and developmental activities that increase adaptive capacity among the government and non-government institutions as it would be of crucial importance for an efficient, effective and equitable adaptation, and yield immediate benefits irrespective of how and at what pace the climatic changes occur (Fankhauser and Burton, 2011).
- For adapting to the changing climate in the forestry sector the immediate need is for research into vulnerability assessment of critical ecosystems and of key species of flora and fauna.
- Higher investments and induction of technology in forest fire and disease control management are required.

Forestry is more than ecological management

- Keeping millions of hectare of forest lands allowing trees to die of age and disease, creating no employment and little incomes, can not earn people's support for keeping one third of land under forest cover.
- A forester's job has to be much more comprehensive - must use land appropriately both ecologically and economically.
- Enhancing productivity as important as ecologically sound management.
- A balance has to be found which may not always be achievable in every bit of forests but can perhaps be achieved over larger landscapes.
- Need to bring the focus back to comprehensive forestry in which economic productivity is not an abusive word.
- The increasing demand for mitigation of climate change through carbon sequestration might perhaps cause the changes needed in our forestry practices.

References

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- FAO Forest Resources Assessment 2005
- Kishwan et al 2009
- Pan et al, Science, 2011
- Yin et al, 2011
Ecosystems

- Study of how organisms interact with each other and with the biotic environment
- Organism -> species -> population -> community -> ecosystem
- Each species has a range of tolerance – physical/chemical environmental, biotic/abiotic factors
- Purpose of an organism – to reproduce successfully, ensure offspring reproduce successfully with genetic variation as the lowest energy cost.
- Adaptations – chemical / physical / behavioral changes to increase survival rates

**ECOSYSTEM STRUCTURE:**
- PRODUCER-CONSUMER-DECOMPOSER
- GEOMORPHOLOGY
- ENDEMISM
- EXTINCTION VERTICES
- FLORISTICS
- MOLECULAR ECOLOGY
- LANDSCAPE ECOLOGY
- POPULATION BIOLOGY
- GIS STUDIES

Dr. S. BALAJI I.F.S
ADDITIONAL PRINCIPAL CHIEF CONSERVATOR OF FORESTS & DIRECTOR
TAMIL NADU FOREST ACADEMY, COIMBATORE

ECO SYSTEMS RESILIENCE AND FOREST BIODIVERSITY ENHANCEMENT THROUGH JOINT FOREST MANAGEMENT – TAMIL NADU EXPERIENCE
Principles of Ecosystem Functioning

- Life on earth is sustained by
  - Solar energy
  - Gravity
  - Water cycle
  - Primary productivity
  - Energy flow
  - Trophic levels
  - Nutrient cycling
- Ecosystems run on solar energy.
- Nutrients are recycled in an ecosystem.
- Ecosystems cannot support large numbers of top consumers

The net primary productivity of biomes

TAMIL NADU PROFILE

- Total geographical area: 130,058 Sq. kms.
- Total Forest area: 22,870 Sq. kms.
- % of Forest area: 17.584%
- Total annual average rainfall: 900 – 1200 mm.
- Total population: 62.11 Million
- Total No. of villages: 17,272 villages

Shola forests and montane grasslands

Tropical Wet evergreen forests, Muthakuzhivayal
Mangrove Forests in Nagapattinam District

Elephants in Nilgiris District

PRESSURES ON TAMIL NADU FORESTS LEADING TO DEGRADATION

HEAD LOAD REMOVAL — FIRE — GRAZING — ULTIMATE DEGRADATION

TAMIL NADU AFFORESTATION PROJECT

- A JFM based project.
- Eco-restoration with watershed development approach.
- Aimed at reducing the poverty level of the forest dependent people.
- Participation of line departments / agencies in the holistic development of forest fringe people.
- Infrastructure development and HRD to enhance capability of TNFD.

TAP PHASE-I (1997-98 to 2004-05)

ACTIVITIES

- Afforestation
  - 4.80 lakh ha.
- Water harvesting
  - Check dams: 23,454 Nos.
  - Percolation ponds: 2,201 Nos.
  - Storage capacity: 817.53 million cft.
- Formation of VFCs: 1,367 Nos.
- Formation of SHGs: 3,891 Nos. (60,097 Women beneficiaries)
- Project expenditure: Rs. 688 crores (17330 million Yen)

ACHIEVEMENTS

- Head load removal
- Fire
- Grazing

<< Back to contents
SOCIO-ECONOMIC STUDY OF TAP

- TAP has reached to 47% of the under-privileged sections of society (24% ST & 23% SC)
- 93% of the beneficiaries are landless and marginal farmers.
- 45% of beneficiaries households belong to Below Poverty Line (BPL).
- 30% of beneficiaries took up new economic activity from TAP micro-credit.
- 32% of beneficiaries improved their existing economic activities.
- 77% reported an incremental annual income up to Rs. 10,000/- and 17% reported an increase between Rs. 10,000 to Rs. 15,000/-.

Study conducted by Economic Perspectives, Chennai-18.
Total No. of villages studied – 30 villages in 7 Agro-climatic zones
Study period – 2008.
**STATISTICAL ANALYSIS**

<table>
<thead>
<tr>
<th>Species Richness</th>
<th>Soil Parameters</th>
<th>Bioindicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>NS</td>
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<tr>
<td>Path analysis</td>
<td>Rainy days</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

**Total Plant Population**

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Climatic Factors</th>
<th>Soil Parameters</th>
<th>Bioindicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path analysis</td>
<td>Rainy days</td>
<td>O.M, N and P</td>
<td>Birds, Actino, and Fungi</td>
</tr>
<tr>
<td>Regression</td>
<td>Temp. and RF</td>
<td>N, O.M</td>
<td>Birds, Butterflies</td>
</tr>
</tbody>
</table>

**Statistical Analysis**

**Shannon-Wiener Index**

\[
H' = - \sum p_i \times \ln p_i
\]

Where \( H' \) is diversity

This index is strongly influenced by species richness but the effect of sample size is low.

The Shannon-Wiener index (1963) and Simpson’s Index (1949) are currently used to measure the species richness and diversity, increasing sample size (Carpentier et al., 1998).

They take into account not only the number of species but also the relative abundance. The Shannon-Wiener Index is based on information theory while the Simpson’s Index (Simpson, 1943) is based on probability theory.
Forests and Climate change

**INDIAN FORESTS**

- The carbon stock in Indian forests is estimated to be 6622 million tonnes.
- Sequestration of Indian forests is showing an annual increase of 138 million tonnes of CO₂ while that of China is showing an annual increase of 301.23 million tonnes of CO₂.
- Over 50% of the forested grids in the country in BIOME 4 will be impacted due to global warming.
- May lead to altitudinal and latitudinal shift of species.
- Increased occurrence of fire, invasive species;
- the Change in species assemblage may lead to enhanced vulnerability.

**GLOBAL FORESTS and CLIMATE CHANGE**

- An increase of (CO₂e) of GHGs from 430 Parts per million (ppm) now to 550 ppm by 2035 is expected.
- Forests are the single "large and persistent" carbon sink with a size of 2,420.4 Gt C/year averaged over two decades beginning 1990.
- This is about 27% of the current levels of annual anthropogenic carbon emissions (Pan et al., 2011).
- The carbon storage of Global Forests is 638 Gt.
- GHG emission from deforestation is 17.4%.
- CoP 16 of UNFCCC held in Cancun approved REDD+ (Reducing Emissions from Deforestation and degradation) as a new approach to conserve the existing Forests.

**Biodiversity prospecting**

**SOCIAL SILVICULTURE**

- Jallithupatti
  - Fuelwood
    1. Acacia planifrons
    2. Albizia amara
    3. Drypetes sepium
    4. Erythroxylon montgomery
    5. Euphorbia antisyosmum
    6. Ficus bengalensis
    7. Ixora pavetta
    8. Jatropha curcus
    9. Ziziphus jujuba
  - Small timber
    1. Acacia leucophloea
    2. Albizia amara
    3. Azadirachta indica
    4. Chloroxylon swietenia
    5. Dichrostachys cinerea
    6. Harwickia binata
    7. Ixora pavetta
    8. Manilkara hexandra
    9. Santalum album
  - Ornamental trees
    1. Cassia occidentalis
    2. Cassia fistula
    3. Stereospermum personatum
  - Edible fruits
    1. Hardwickia binata
    2. Jatropha curcus
    3. Opuntia elatior
    4. Phoenix sylvestris
    5. Randia uliginosa
    6. Ziziphus jujuba
    7. Ziziphus oenoplia
    8. Sudali
    9. Kavalakkilangu
  - Medicinal plants
    1. Andrographis serpyfolia
    2. Asparagus racemosus
    3. Blumea virens
    4. Cassia fistula
    5. Erythorxylon monogynum
    6. Evolvulus alisinoides
    7. Jatropha curcus
    8. Justicia tranquebarensis
    9. Kleinia grandiflora
    10. Phyllanthus amarus
    11. Totalia asiatica
    12. Vettuvaithazhai
  - Cultural uses
    1. Tarenna aisatica

**PROJECT IMPACT ON**

- Ecology
- Social economy
- Hydrology

**MICRO-CREDIT DISTRIBUTION**

- People’s representative issuing loan to villagers in 2007:
  - Odaipatti TAP village of Virudhunagar circle.
- Loan issued to forest dependents in 2005:
  - Bheemanpuram TAP village of Salem circle.

**SENGANATTAM 1997-98 TAP VILLAGE**

- Issue of loans to villagers for IGA by Dr. L. Kannan, Member, State Forest Commission in Sathy Divn.

**INTEGRATING PHYSICAL AND SOCIAL VARIOUS**

- Forestry services in 1998
- Social credit services in 1998
SUSTAINABILITY: SWIM to keep JFM afloat

- Sustainability of JFM
- Maintaining Sustained interest of People
- VFC Management by Gram Sabha
- Implementation of Forest Rights Act 2006
- Supreme court ban on cutting Naturally grown Trees
- Augmenting Tangible Benefits from Forests such as thinned poles, NTFP etc. on sustainable basis.
- Revolving SHG loan amount effectively-KMTR Model.
- Inter-Sectoral Linkage for sustainable Rural Livelihood
- Social Silviculture

CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

Sustainable use of components and fair and equitable sharing of benefits arising out of the utilization of genetic resources including by appropriate access to genetic resources and by appropriate transfer of relevant technologies taking into account all rights over those resources and technologies and by appropriate funding - Article 1 of CBD

GREEN INDIA MISSION

- Government of India has embarked on Eight Missions to check the ill effects of Climate Change including the Green India Mission to improve Forest density and increase Green cover.
- Increased forest/tree cover over on 5 m ha.
- Improved quality forest cover 5 million ha.
- Improved ecosystem services including biodiversity, hydrological services and carbon sequestration
- Increased forest based livelihood income of 3 million households living in and around forests.
- Enhanced CO2 sequestration by 50 to 60 tonnes.

OUTCOME AFTER A DECADE OF JFM

| Sustainable conservation | Vegetation has visibly increased in degraded forests
|                         | Biotic pressure considerably reduced.
|                         | Ensured better community protection.
| Sustainable participation | VFCs given legal backup by registration under Societies Act.
|                         | VFDF placed at the disposal of VFC for development.
| Economic sustainability  | Income level of households has increased.
|                         | Loan recovery amount credited into VFDF to maintain flow of funds.
|                         | SHGs have accessed institutional finance
|                         | Fines, MFP sale revenue added to the VFDF
|                         | Deep-rooted inter sectoral linkage

CHALLENGES IN JFM

- Sustainability of JFM
- Maintaining Sustained interest of People
- VFC Management by Gram Sabha
- Implementation of Forest Rights Act 2006
- Supreme court ban on cutting Naturally grown Trees
- Augmenting Tangible Benefits from Forests such as thinned poles, NTFP etc. on sustainable basis.
- Revolving SHG loan amount effectively-KMTR Model.
- Inter-Sectoral Linkage for sustainable Rural Livelihood
- Social Silviculture
India and REDD+: Opportunities and Challenges of Implementation

23 November 2011
Indian Forest Congress 2011, New Delhi

Dr. Renu Singh
Head, Biodiversity and Climate Change Division
Indian Council of Forestry Research and Education, Dehradun

Outline
1. Forests and Climate Change Mitigation
2. REDD+ under the UNFCCC: Scope for India’s Forests
3. The Cancun Agreements and Opportunities of Implementation in India
4. Issues and Challenges of Implementation for India

Forests and Climate Change
- Forests are both sources and sinks of carbon
- Total C content of forest ecosystem estimated about 652 GtC, which is more than the entire atmosphere
- Global deforestation rate – 13 million hectares per yr leading to about 17.4% of global GHG emissions (5.8 Gt CO₂/yr)
- In the period 2005-2010, carbon stocks in forest biomass decreased by 0.5 Gt of carbon annually
- Forests provide ecosystem goods and services to communities to cope up with climate change

Development of REDD under UNFCCC
(Reducing emissions from deforestation and degradation in developing countries)
- Attention on high deforestation in Brazil, Indonesia, Bolivia
- Deforestation requires same focus as other sectors like energy, industry and transport to check GHG emissions
- New agenda item (Reducing emissions from deforestation in developing countries) proposed by Papua New Guinea and Costa Rica at COP 11 in Montreal in 2005

REDD under UNFCCC Contd...
- COP 11 invited parties for submission of views on the agenda
- SBSTA initiated work related to technical issues
- Developing countries to participate voluntarily in forestry based mitigation actions; developed countries to provide compensation/incentives

Policy Approaches Negotiated
2. Stabilisation of Forest: Stressed by Cameroon, Gabon, and other Congo Basin countries. Asks for compensation for stabilizing forest cover.
3. Compensated Conservation: Proposed by India. Argues for compensation for conserving and increasing forest cover.

Ten Countries with the Largest Forest Area, 2010
Account for two-thirds of total forest area

Source: FAO 2010, FRA

Annual Change in Forest Area by Country, 2005–2010
Ten Countries with Largest Annual Net Gain in Forest Area, 1990–2010

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<thead>
<tr>
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<tbody>
<tr>
<td>China</td>
<td>1,986 1.20</td>
<td>Spain</td>
<td>2,09 317</td>
</tr>
<tr>
<td>United States of America</td>
<td>0.13 386</td>
<td>Viet Nam</td>
<td>2.28 236</td>
</tr>
<tr>
<td>India</td>
<td>0.55 145</td>
<td>Turkey</td>
<td>1.11 119</td>
</tr>
<tr>
<td>Spain</td>
<td>0.68 52</td>
<td>Sweden</td>
<td>0.29 78</td>
</tr>
<tr>
<td>Italy</td>
<td>0.90 57</td>
<td>Italy</td>
<td>0.90 78</td>
</tr>
<tr>
<td>Finland</td>
<td>0.79 57</td>
<td>France</td>
<td>0.38 55</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.38 55</td>
<td>Total</td>
<td>0.55 3,399</td>
</tr>
<tr>
<td>Total</td>
<td>0.67 4,414</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: FAO 2010

Ten Countries with Largest Annual Net Loss of Forest Area, 1990–2010

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Brazil</td>
<td>-2.80 -3.71</td>
<td>Brazil</td>
<td>-2.04 -3.35</td>
</tr>
<tr>
<td>Indonesia</td>
<td>-1.94 -4.35</td>
<td>Australia</td>
<td>0.52 0.37</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.86 -0.86</td>
<td>Jordan</td>
<td>-0.49 -0.61</td>
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<tr>
<td>Myanmar</td>
<td>-1.77 -0.41</td>
<td>Mongolia</td>
<td>-1.10 -0.67</td>
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<tr>
<td>Vietnam</td>
<td>-0.80 -1.46</td>
<td>United Republic of Tanzania</td>
<td>-0.43 -1.15</td>
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<tr>
<td>United Kingdom</td>
<td>-0.86 -1.46</td>
<td>Democratic Republic of the Congo</td>
<td>-0.57 -1.88</td>
</tr>
<tr>
<td>Mexico</td>
<td>-0.82 -0.82</td>
<td>Democratic Republic of the Congo</td>
<td>-0.57 -1.88</td>
</tr>
<tr>
<td>Argentina</td>
<td>-0.86 -0.86</td>
<td>Venezuela (Bolivarian Republic)</td>
<td>-0.09 -0.60</td>
</tr>
<tr>
<td>Total</td>
<td>-0.86 -0.86</td>
<td>Total</td>
<td>-0.86 -0.86</td>
</tr>
</tbody>
</table>

Source: FAO 2010

Projected Trend in India’s Forest Cover and C Stocks under the Current Trend Scenario

Projections of forest carbon stocks – Increase from 8.79 GtC in 2005 to 9.75 GtC in 2030
(Source: IISc, 2006)

SNC estimates- 7.29 Gt in 2005 to 7.33 Gt in 2007

India’s Case for Compensated Conservation

- Project Compensated Conservation as an alternative to Compensated Reduction
- Practically no clearfelling/deforestation in India, forest cover stabilized
- Best option: Conservation Approach

REDD in the Bali Conference (COP 13)

Discussions focused on
- Inclusion of conservation and enhancement of forest carbon stocks (proposed by India and supported by China, Columbia, Bhutan, Pakistan, Bangladesh, Congo Basin countries, and Philippines; opposed by Brazil, Japan, the EU, and some of the Latin American countries)
- Consideration of deforestation in the context of discussions on long-term cooperative action under the UNFCCC

COP 13: Decision on REDD

Para 7(a) of Decision 2/CP.13

“...Inviting Parties to submit, by 21 March 2008, their views on how to address outstanding methodological issues including, inter alia, assessments of changes in forest cover and associated carbon stocks and greenhouse gas emissions, incremental changes due to sustainable management of the forest...”

[727]
Bali Action Plan

“...Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries...”

Implication for India

REDD+ policy approach provides possibility of seeking incentives for compensation for pro conservation approach and sustainable management of forests resulting in the increase of forest carbon stocks

The Cancun Agreements and Opportunities of Implementation in India

COP 16 (Cancun) Decision on REDD+

- Aims to slow, halt, and reverse forest cover and carbon loss
- **Scope:** Countries to undertake following activities according to their respective capabilities and national circumstances
  - Reducing emissions from deforestation
  - Reducing emissions from forest degradation
  - Conservation of forest carbon stocks
  - Sustainable management of forest
  - Enhancement of forest carbon stocks

COP 16 Decision Contd...

Provision of adequate and predictable support in terms of finance and technology to develop the following elements:

- A national strategy or action plan
- A national (interim measure- subnational) forest reference emission level and/or forest reference level
- A robust and transparent national forest monitoring system for MRV of the activities
- A system for information on safeguards assurance in implementation of the activities

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Forests and Climate change

Countries to address
- Drivers of deforestation and forest degradation,
- Land tenure issues,
- Forest governance issues,
- Gender considerations
- Effective participation of relevant stakeholders
- Safeguards

COP 16 Decision Contd...

Safeguards
Activities
- To be consistent with the objective of environmental integrity
- Parties' national sustainable development needs
- Consider multiple functions of forests and other ecosystems
- Supported by adequate and predictable financial and technology support including capacity-building
- Promote sustainable management of forests
- Promote conservation of natural forests, biological diversity, and enhance social and environmental benefits

Implementation Opportunities: India’s Conservation Oriented Policy Framework
Governance issues
- Indian Forest Acts (1865, 1878, and 1927)
  - Forest department created in 1864
  - Provide legal framework for forestry administration and regulation in the country
- Forest (Conservation) Act 1980
  - 1951-1980 forestland diverted – 4,328 million ha
  - 1988 ban on clearfelling
  - Reduced the rate of deforestation of forestland from 0.15 million ha per year to about 1,600 ha per year

Implementation Opportunities Contd...
Safeguards to promote conservation of biological diversity and natural forests
- Wildlife (Protection) Act 1972
  - Provides for the protection of wild animals and plants
  - Creation of a network of protected areas such as national parks, wildlife sanctuaries, conservation reserves
  - Approx. 4.75% of the total geographical area under in situ conservation through a ‘Protected Area’ network
- Biological Diversity Act 2002
  - States long term conservation and protection of biological resources of the country
- National Environment Policy 2006
  - Environmental, livelihood, and financial benefits
  - Calls for enhancing the density of natural forests

Implementation Opportunities Contd...
Safeguards to promote conservation of biological diversity and natural forests
- National Biodiversity Action Plan (NBAP) 2008
  - Central to achieving the objectives of the CBD
  - Considers the global threat of climate change,
  - Promotes holistic approach to conservation, enhancement, and sustainable utilization of biodiversity
  - Aims at developing and integrating biodiversity information from diverse sources into a national database,
  - Inventorization of country's floristic, faunal, and microbial resources with special attention to endangered and endemic species
  - Would be helpful in developing systems under REDD+ for providing information on safeguards related to biodiversity and natural forests conditions
Implementation Opportunities Contd...

Meeting the requirements of land tenure and forest governance issues, gender considerations, effective participation of relevant stakeholders, and safeguards to enhance social and environmental benefits

- National Forest Policy 1988
  - Aims to combine the objectives of environmental stability and bio-diversity conservation with those of social justice
  - Prohibits clearfelling of natural forests and introduction of exotics
  - Discourages diversion of forests for non-forestry purposes
  - Recognizes the rights of the rural communities
  - Envisages creation of a massive people’s movement with the involvement of women

- June 1990 and 2000 Guidelines for Joint Forest Management
  - Provides operational frameworks for participatory forest management
  - Legal backup for JFM committees
  - Enhanced participation of women in the process

- Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006
  - Provisions of settling tenure and other rights to forest dwelling communities and individuals

Green India Mission, 2010

- One of the eight Missions under the NAPCC
- Recognizes climate change impacts
- Objectives
  - Increase forest/tree cover on 5 m ha of lands and improve quality of forest cover on another 5 m ha of lands
  - Improved ecosystem services including biodiversity, hydrological services and carbon sequestration
  - Increased forest-based livelihood income of about 3 million households living in and around the forests
- Key role for local communities and decentralized governance
- Revamping and capacity building of village institutions (JFMCs) and Forest Departments

Issues and Challenges of Implementation for India

National Coordination Mechanism

- MoEF deals with the environment and forests administration – responsible for REDD+ process and implementation
- ‘Coordinating Committee’ in forestry wing in January 2011
- REDD+ Cell in the MoEF – suggested tasks
  - Developing a national REDD+ strategy and action plan
  - Identifying and analyzing the scope of REDD+ activities for national implementation
  - Aligning the strategy with other development strategies of the country like NAPCC and GIM
  - Initiate dialogue with relevant stakeholder groups

- Rights and responsibilities of different levels of governments
- Developing equitable benefit sharing mechanism from national to local level
- Sources of finance for REDD+
- Identifying and establishing the network of technical institutions for MRV systems
- Coordination, monitoring, and reviewing the implementation at national level
- Interaction and reporting to relevant international bodies

<< Back to contents
Institutionalization of MRV Systems
- Establishment of robust and transparent national MRV systems
- Forest C Inventories - Estimation of removals/changes in C Stocks
- National accounting system
- Baseline and forest reference levels
- Identification of institutions (FSI, ICFRE, IIRS, WII, IISc., SFDs)
- Capacity building

Financing REDD+ in India
- Initial investments – domestic funds, expects UNFCCC funds in future
- GIM, National Afforestation Programme, agriculture and rural development sector programmes - annually add or improve 2 million ha of forest and tree cover (annual incremental addition of 2 million tonnes of carbon)
- Require an investment of USD 2 billion every year for 10 years
- Specific fund allocation for REDD+?

Dynamics and Challenges of Resource Use
- India, having 2.5% of world’s geographic area and 1.8% of world’s forests, sustains 16% of planet’s human population and 18% of livestock population
- In 2005 and 2007, moderately dense forest net loss – 936 km2, open forest net increase - 1,626 km2
- Productivity
  - India - 0.7 m3/ha/yr, World - 2.1 m3/ha/yr
  - Per capita forests
    - India - 0.07 ha, World - 0.62 ha
  - 70 million tribal and 200 million non-tribal rural people defined as forest-dependent

Dynamics Contd...
- Forest products contribute 20-40% of total income of households in forest areas
- NTFPs provide 55% of total employment in the forest sector
- Fuelwood consumption to go up from 250/300 million m3 in 2000 to 400 million m3 in 2020
- Industrial demand of wood to go up from 58 million m3 in the year 2000 to 153 million m3 in the year 2020

Community Participation
- Integrate local communities concerns and participation, information, capacity building
- An additional co-benefit, more monetary carbon benefits
- Institution of JFM to be linked
- Settings are diverse, generalisations about implementation are not easy
- Different classes will require different degree of assurance (vulnerable groups - women, poor)
- Careful consideration beyond JFM, especially equitable benefit distribution from REDD+ to forest communities

Grazing pressures:
- 78% forest area affected
  - 270 million cattle graze inside forest
  - 175 to 200 m tonnes of green fodder collected through lopping and harvesting of grasses
- Forest fires affecting about 1.45 to 3.73 mha area annually

Dynamics Contd...
REDD+ Research and Demonstration Activities in India

- Dedicated funds to support REDD+ research
- Capacity building of research institutions
- Demonstration projects with internal/external funding
- Forest Carbon Partnership Facility for REDD+
- UN REDD Programme
- Bilateral/Multilateral support
  
Pilot projects in a number of countries

Still to be Explored by UNFCCC

- AWG-LCA to explore financing options for full implementation
- Methodological guidance on the estimation and contribution of emissions and removals from LULUCF activities in developing countries to the mitigation of climate change (SBSTA)
- Methodological guidance for reference levels (SBSTA)
- Modalities for MRV of REDD+ actions (SBSTA)
- Guidance for developing a system for information on safeguards (SBSTA)

Thanks!

For further information, please contact:
renusingh@icfre.org
Indian Forest Carbon Cycle Assessment

V.K. Dadhwal, M.S.R. Murthy*, S.P.S. Kushwaha, Sarnam Singh, Ravindra Naik

National Remote Sensing Centre

Indian Forest Congress, Delhi, 23rd Nov, 2011

National Assessments – Approaches
(Based on 14 National Assessments)

- National level Forest areas and BEF
- RS based National level areas, Strata level BEF at National level
- State wise RS based areas & State wise, Strata wise BEF
- District wise areas, State wise, Strata wise BEF

Kishwan et al., and Subodh et al., 2011 – Net Sink

Factors Driving

- Spatial and Temporal Explicitness
  - Forest cover and standing biomass
- Precise Forest allometric databases
  - Scale and Parameters
- Uncertainty assessment and Controlling
  - Data collection, Design, Estimation
National Carbon Project

- **GOALS**
  - Assessment of Carbon Pools, Fluxes and Net Carbon balance for terrestrial biosphere in India
  - To establish a observational network and remote sensing-based spatial databases for modeling and periodic assessment of carbon balance
  - To provide support to national activity with respect to carbon balance under National Communication to UNFCCC

- **Sub Projects**
  - Vegetation Carbon Pools
  - Soil Carbon Pools
  - Soil Vegetation Atmospheric Fluxes

Spatial Biomass Assessment – Field Data Collection

- 6500 field plot data from forests and trees outside forests
- 1250 permanent sample plots (one at each cluster)
- 54 institutions and 74 PIs
- 16 test-sites in different ecological regions spectral modeling using optical and microwave data in forest ecosystem.
- Seasonal crop biomass/NPP estimation using remote sensing and modeling
- Crop NPP (above and below ground) from historical agricultural statistics data

Methodology

**RS Data**
- Time series Analysis

**Spatial data**
- Plot locations
  - Basal area for selected trees
  - Seasonality derived from MODIS

**Statistical modeling**
- Random Forest
  - Ensemble classifier consisting of many decision trees
- K-Nearest Neighbor
  - Imputation
- Error Estimates
  - Variable importance index
  - Error estimates
  - Spatial Basal Area* estimate

*Tree basal area significant predictor of total above ground biomass

Vegetation Carbon Pools and Dynamics

VCPD

Spatial Biomass - Modeling and Assessment

**Current Method – Assessment**
- RS derived strata and field inventory.
- Field intensive - less suitable for regional, national periodic monitoring.

**New Techniques – Data mining techniques**
- Non-parametric self learning method
- Multi-variate analysis
- Resistant to outliers and noisy data
- Estimation of error structure.

Objective
- To produce spatial estimates of Biomass using Data mining Techniques.

Input Data
- 16-Day composited 250m MODIS EVI data (2006-2008)
- 1700 field inventory plots (2007)
- Climate, Topography

Results

- Predicted Basal Area (m² ha⁻¹)

Way Forward
- Operational Methodology- regional Biomass estimates using Awifs.
- Inclusion of RS derived stand height to improve accuracy and optimization of field inputs.
National level Assessment of Trees Outside Forests using multi-resolution IRS data

Rationale:
Agroforestry gives livelihood support, Mitigation and Adaptation measure
Trees Outside Forests increasing due to public and private initiatives
IRS (Cartosat PAN/LISS IV) sensors are pivotal to provide parameterization on TOF

Current Assessment:
National level sampling by Forest Survey of India across 16 geo-blocks to provide state-wise statistics

Proposed Assessment:
Geospatial sampling design integrating multi-resolution satellite data to provide district level statistics of TOF.

National Geospatial Framework

- National zonation available based on Basin limits, physiography (~200 zones) (A)
- 5X5 km grids in each zone
- Telangana plateau considered for the pilot (B)
- Gridwise estimate of ‘Determinants’ (C)
- Counting trees in Sample grids. Sample grids by stratified random method.
- Regionalised Estimates using factor (of gridwise determinant quantity) (D)


<table>
<thead>
<tr>
<th>Year</th>
<th>Area (km²)</th>
<th>% of TGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>81785.6</td>
<td>52.5</td>
</tr>
<tr>
<td>1973</td>
<td>56661.1</td>
<td>36.4</td>
</tr>
<tr>
<td>1985</td>
<td>51642.3</td>
<td>33.2</td>
</tr>
<tr>
<td>1995</td>
<td>49773.0</td>
<td>32.0</td>
</tr>
<tr>
<td>2009</td>
<td>48669.4</td>
<td>31.3</td>
</tr>
</tbody>
</table>

616 forest grids have no change in forest cover
### Soil Carbon Pools and Dynamics

**SCP D**

### Forest Soil OC Pool for SNC – ICFRE & IIRS

550 New Forest Soil Samples

Pools estimated from above densities

1995 - 3.551 PgC

2005 - 3.754 PgC

### Soil Vegetation - Atmosphere Fluxes

**SVAF**

### Soil Vegetation Atmosphere Fluxes

Establishment of Towers and Data Assimilation

#### Implementation Steps
- Site Selection
- MOU / Forest Dept
- AA/DGCA Approval
- Site Infrastructure
- Tower
- Instrument installation
- Operational with field data

#### Status of Flux-Tower Operation

<table>
<thead>
<tr>
<th>No.</th>
<th>Site</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Haldwani</td>
<td>Forest</td>
</tr>
<tr>
<td>2</td>
<td>Meerut</td>
<td>Agriculture</td>
</tr>
<tr>
<td>3</td>
<td>Barakot</td>
<td>Forest</td>
</tr>
<tr>
<td></td>
<td>Commissiated</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Betul</td>
<td>Forest</td>
</tr>
<tr>
<td>5</td>
<td>Sundarbans</td>
<td>Forest</td>
</tr>
</tbody>
</table>

**Sites Selected**
- Khudra: Forest
- Dandeli/Tithimathi: Forest

**Proposed**
- Gujarat/Rajasthan: Forest
- Tamilnadu/Annamalai: Forest
- Maharashtra: Agriculture
- Andhra Pradesh: Agriculture

**Operational**
- Under Installation
- Planned

### NATIONAL CARBON PROJECT-SPATIAL ASSESSMENT OF SOIL CARBON POOL OF INDIA

**OBJECTIVES**
- To estimate soil organic carbon and inorganic carbon stocks of the country
- To generate spatial dataset of soil carbon stocks

**APPROACH**
- Sampling points were identified based on land use, physiography and AESR
- 20 PI'S were associated in the collection of soil samples
- Analysis of soil samples with CHN Analyser for organic C, inorganic C, Total C
- Bulk density determination using core or clod method
- Creation of digital database

**STATUS**
- No. of soil samples collected = 6200
- Analysis Completed = 4400
- Remaining in progress

**Spatial data modeling of Soil carbon is in progress.**
Forests and Climate change

**Flux Tower : Net Carbon Exchange, Haldwani**

Diurnal variation in net ecosystem CO2 exchange at key phenophases over mixed forest plantation

**Long Term NPP Trends using CASA based simulations: 1981-2005**

- Average annual NPP 1.5 Pg C Yr-1
- Increasing at the rate of 0.005 Pg C Yr-2
- Trend is equivalent to 8.5%

On an average India is the region of net sink of atmospheric CO2 with total annual uptake of 9.5 Tg C yr-1.

**Mean and trends in NPP and SOC (CASA, NOAA-AVHRR 1981-2003)**

Annual Climatology of NPP and SOC

**Challenges - Future Plans**

- Optimization of field sampling
- Satellite derived height and inversion
- Localised field data on BEF and extractions
- Spatial disaggregated models – Regional biomass assessments methods
- Chronosequenced Soil Sampling
- Soil-Vegetation –Atmosphere flux databases
- Biospheric modelling
- National Frame work – Multi model estimations and uncertainty reduction

**Soil Vegetation Atmosphere Fluxes (SVF)
12th FYP Proposal**

- Continuity of the SVF tower sites from 11th five year plan
- Establishing new towers at forest and agriculture sites
- RS based up scaling and assessment of NPP over forest and agriculture sites,
- Coupling with bio-spheric and atmospheric models for carbon cycle modeling and simulation
- Development of carbon flux database system

**Thank You!**
Carbon Fluxes Simulation and Modeling – Studies Carried out

Simulation of CO₂ fluxes in the form of NPP, NEP, SOC and C-stocks 1981-2006

- Different pools of the terrestrial system at monthly scale using CASA model
- Study on variability of NPP and NEP and other parameters were carried out
- Refinement of several biophysical parameters

Simulation of CO₂ fluxes at ocean atmosphere interface over the Indian Ocean (1981-2006)

- Key parameters of CO₂ exchange process - del pCO₂, wind speed, SST, SSS

Mid tropo-spheric CO₂ data measured by Atmospheric Infra-Red Sounder (AIRS) (2002-08)

- Study variability of atmospheric CO₂ and its control through surface fluxes over India and surrounding oceans.
Soil and Carbon Sequestration

- Concentration of atmospheric CO₂ can be lowered either by reducing emissions or by taking CO₂ out from the atmosphere and stored in the terrestrial ecosystem.
- Soil plays an important role in carbon sequestration by increasing soil organic carbon pool. Carbon pool in the soil is higher than the vegetation carbon pool.
- Soil Organic Carbon (SOC) has been ignored since long but due to climate change awareness, its importance has recognized.

Soils and Carbon Sequestration

- GHGs re-emit some of heat to the earth's surface. If they did not perform this useful function, most of the heat energy would escape, leaving the earth cold (about -18 °C) and unfit to support life.
- Carbon dioxide is one of the major greenhouse gases and it has increased significantly in recent decades.
- CH₄, Nitrous oxide, Chlorofluorocarbon Hydro-fluorocarbons and Per-fluorocarbons are the other GHGs.

Carbon Sequestration: Organic Carbon Store in the Soils under Chir (Pinus roxburghii) Forests at Different Altitudes in Uttarakhand State of India

M.K. Gupta and S.D. Sharma
Forest Research Institute, Dehra Dun
IPCC has recognized soil organic carbon pool as one of the five major carbon pools for LULUCF sector.

It is mandatory to all nations to provide soil organic carbon pool and changes in the forest soils in LULUCF sector under National Communications to the UNFCCC.

Soil organic carbon is sensitive to impact of anthropogenic activities. The conversion of natural vegetation to various land uses results in decline in soil organic matter.

The researcher has estimated soil organic carbon simply as one of the soil attributes. To calculate soil organic carbon pool from this data, several assumptions have to be made, which lead to high uncertainties in SOC store data.

Soil Organic Carbon Pool Estimation

Very few studies have been undertaken to estimate the soil organic carbon in forests, by following standard uniform methodology for field and laboratory work.

- Estimation of Bulk density and Coarse fragments of soil is very important to reduce the uncertainty about the weight of soil of the study area.
- No scientific benchmark information are available to ascertain the changes in SOC pool over the period of time.

Details of the sites under different land uses

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Altitude Range (m)</th>
<th>Districts Covered</th>
<th>Area Covered (Forest Ranges)</th>
<th>No. of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 1000</td>
<td>Pauri Garhwal,</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rudraprayag, Chamoli, Dehra Dun, Champawat, Bageshwer, Pithoragarh, Kosi, Utrai Dam, Nainital, Kosi, Pauri, Bageshwer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1001–1500</td>
<td>Tehri Garhwal, Nainital, Almora, Tehri, Rudraprayag, Chamoli, Kosi, Pauri, Bageshwer</td>
<td>329</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1501–2000</td>
<td>Tehri Garhwal, Nainital, Almora, Chamoli, Kosi, Pauri, Bageshwer</td>
<td>364</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&gt; 2001</td>
<td>Uttarkashi, Dehra Dun, Almora, Chamoli, Kosi, Pauri, Bageshwer, Pithoragarh</td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>Total 834</td>
<td></td>
</tr>
</tbody>
</table>

Share of total SOC pool occupied at different altitudes

Soil organic carbon pool under Chir pine at different altitudes

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Altitude (m)</th>
<th>SOC Pool (t ha⁻¹)</th>
<th>SD</th>
<th>Mitigation Potential</th>
<th>SE</th>
<th>Confidence Interval (t ha⁻¹)</th>
<th>Lower bound</th>
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<tr>
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<td>49.27 ± 10.92</td>
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<tr>
<td>State</td>
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<td>61.10 ± 15.46</td>
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<td>1.00</td>
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Some alphabets represent statistically at par group
SD - Standard Deviation; SE - Standard Error

Uttarakhand State

Soil organic carbon pool estimated at different altitudes

1st Indian Forest Congress - 2011

a very prominent forest cover in Uttarakhand. Out of total i.e. 24,414.80 km² area under forests, Chir occupied 3,943.83 km² in the state which is 16.15 % of total forest area of the state.

This study was carried out under Chir pine forests at different altitudes in Uttarakhand.

The data for SOC calculated by using the following equation as suggested by IPCC Good Practice Guidance for LULUCF (2003):

\[
\text{SOC pool} = \frac{\text{SOC horizon}}{\text{Horizon}} = \frac{\text{([SOC] \times \text{Bulk density} \times \text{depth} \times (1 – \text{C frag.}) \times 10)}_{\text{Horizon}}}{\text{Horizon}}
\]

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</tr>
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Some alphabets represent statistically at par group
SD - Standard Deviation; SE - Standard Error
Forests and Climate change

TAKE CARE OF ENVIRONMENT

So that we can show the real forests to our future generation instead of photos

How SOC can be increased

Wastelands in India cover more than 100 m ha, and out of which 70 % are carbon degraded, these soils have relatively high potential for accumulating organic carbon in vegetation and in soil

• Normally sub soils are poor in soil organic carbon, to increase the SOC contents in these layers, deep rooted plants should be planted

• Eco friendly organic farming where, all the N, P and K requirements of the plants supplied with organic sources has also a great potential to enrich SOC

Statistically significant mean differences on the basis of CD (LSD)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Altitudes</th>
<th>Mean Difference</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>&lt; 1000 m Vs 1001 – 1500 m</td>
<td>7.1376*</td>
<td>0.009</td>
</tr>
<tr>
<td>2</td>
<td>&lt; 1000 m Vs 1501 – 2001 m</td>
<td>18.1642*</td>
<td>0.000</td>
</tr>
<tr>
<td>3</td>
<td>&lt; 1000 m Vs 2001 m</td>
<td>26.5423*</td>
<td>0.000</td>
</tr>
<tr>
<td>4</td>
<td>1001 – 1500 m Vs 1501 – 2001 m</td>
<td>11.0266*</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>1001 – 1500 m Vs &gt; 2001 m</td>
<td>19.4047*</td>
<td>0.003</td>
</tr>
</tbody>
</table>

* Mean difference is significant at the 0.05 level

• Correlation between altitude and SOC pool under Pinus roxburghii was significantly positive with correlation coefficient 0.96* (Significant at P < 0.05 level).
# Carbon Stock of Trees Outside Forests (2005-2009)

Sparsh Kala, V.K. Dhawan, and Sanjeet Kumar Hom

## Global Warming

- Causing measurable changes in climate and temperature
- Temperature of earth – already risen by 0.6°C since the late 1800s
- More rise of 0.8-4°C is expected
- Expected rise in sea level – 0.28m - 0.43m by 2100

## Causes of Global Warming

<table>
<thead>
<tr>
<th>Major Greenhouse gases</th>
<th>Some Montreal protocol gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Carbon Dioxide (CO₂)</td>
<td>• Bromocarbons</td>
</tr>
<tr>
<td>• Chlorofluoro Carbons (CFCs)</td>
<td></td>
</tr>
<tr>
<td>• Methane (CH₄)</td>
<td>• Carbon Tetrachloride (CCl₄)</td>
</tr>
<tr>
<td>• Nitrous oxide (N₂O)</td>
<td>• Perfluorinated Compounds (PFCs)</td>
</tr>
<tr>
<td>• Methyl Chloroform (CH₃CCl₃)</td>
<td></td>
</tr>
<tr>
<td>• Ozone (O₃)</td>
<td>• Sulphur Hexafluoride (SF₆)</td>
</tr>
</tbody>
</table>

Sparsh Kala, V.K. Dhawan, and Sanjeet Kumar Hom
**Carbon Dioxide (CO₂)**

- Major contributor to Global Warming
- Causes of Carbon dioxide emission
  - Burning of fossil fuels
  - Deforestation
  - Forest degradation
  - Fragmentation
  - Diversion of forest land for non-forest purposes

**Forests as Carbon Sink**

- Remove carbon dioxide from atmosphere through Carbon Sequestration.
- Total forest area of world - 31% of world’s total land area
- Plantation area- 5%, Natural Forests- 95%
- Forest and tree cover in India- 78.37 million ha (23.84% of total geographic area of country)

**Carbon Sequestration**

- Removal of atmospheric carbon dioxide into green plants where it can be stored indefinitely
- Carbon is stored in plant (above ground biomass), roots (below ground biomass) and in soil
- Productivity of carbon sequestration can be increased by creating:
  - Afforestation/Reforestation
  - Agroforestry
  - Increasing productivity of degraded forests

---

**Forest Biomass**

- Above Ground Biomass: All living vegetation above soil (stems, stumps, branches, bark, seeds and foliage)
- Tree biomass
- Below Ground Biomass: Biomass contained within live roots – both organic and inorganic carbon

---

**PLANTING MORE TREES**
**Mathematical assessment of carbon stocks**

\[ C_{\text{carbon}} = C_{\text{biomass}} + C_{\text{soil}} \]

- \( C_{\text{carbon}} \) = Total available carbon (vegetation + soil)
- \( C_{\text{biomass}} = \) AGB + BGB
- \( C_{\text{soil}} = \) Soil Organic Carbon (SOC) up to 30 cm depth

**Objective**

Estimation of carbon storage potential of Trees Outside forests (TOF) from 2005 – 2009

**Why plant trees?**

- To achieve national goal of 33% forest and tree cover
- Plantations provide higher productivity
- Promotion of agro-forestry
- Introduction of exotics

**Concept of trees outside forests**

- Reduce pressure on forests
- Provide raw materials to wood based and paper industries
- Restoration of degraded ecological balance
- Recreational and aesthetic opportunities
- Meet demands of fruit, fodder and fuelwood
- Creating employment opportunities

**Methodology**

- Collection of data: State Forest Report of FSI
- Assessment of data of number of stems and volume according to different diameter classes
- Calculation of carbon stock using suitable conversion factors
- Comparison between carbon stock of 2005 and 2009

**Calculations**

- \( C_{\text{carbon}} = \) Total available carbon (vegetation + soil)
- \( C_{\text{biomass}} = \) AGB + BGB
- \( C_{\text{soil}} = \) Soil Organic Carbon (SOC) up to 30 cm depth
Forests and Climate change

Limitations

- BEF and ratio of below ground to above ground biomass assumed are the average for the entire country. However these factors vary for different sites and localities.
- Mean wood density assumed for different species is the average for the entire country.
- A common MWD has been considered for the tree species for which data were unavailable.
- For the calculation of dry weight and carbon content, the conversion factor assumed is also a constant.

Conclusion

- The study estimates that there was a net decrease of 1.21% in the total carbon sequestered by trees outside forests in year 2005 to 2009.
- The decrease in carbon stock may be due to decrease in number of stems in more than 50 cm diameter class, which stores more carbon as compared to lower diameter classes.
- Even though there is rise in number of stems falling under diameter classes 10-30 cm and 30-50 cm, it might not compensate the decrease in net carbon stock.

Results & Discussions

Above Ground Biomass (AGB) = Volume of Tree X 1.58
(Biomass Expansion Factor (BEF) in Indian Context, Kaul et al)

Below Ground Biomass (BGB) = AGB X 0.27
(Mean ratio of BGB to AGB in Indian Context, Kaul et al)

Total Biomass = AGB + BGB

Total weight = Total Biomass X Mean Wood Density (MWD)

Dry weight = 80% of total weight

Total carbon = 50% of dry weight

<table>
<thead>
<tr>
<th>Diameter class (cm)</th>
<th>Year</th>
<th>No. of Stems (nos. in '000)</th>
<th>Volume (million m³)</th>
<th>Above Ground Biomass (million m³)</th>
<th>Below Ground Biomass (million m³)</th>
<th>Total Biomass (million m³)</th>
<th>Weight (Mt)</th>
<th>Dry wt. (Mt)</th>
<th>Carbon Stock (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-30</td>
<td>2005</td>
<td>43,15,102</td>
<td>549.418</td>
<td>968.08</td>
<td>234.382</td>
<td>1102.46</td>
<td>793.77</td>
<td>635.01</td>
<td>317.50</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>46,32,330</td>
<td>567.455</td>
<td>1077.889</td>
<td>202.39</td>
<td>1179.65</td>
<td>780.55</td>
<td>621.64</td>
<td>328.22</td>
</tr>
<tr>
<td>Increment %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>3.37</strong></td>
</tr>
<tr>
<td>30-50</td>
<td>2005</td>
<td>6,81,000</td>
<td>486.476</td>
<td>771.792</td>
<td>208.384</td>
<td>980.176</td>
<td>715.72</td>
<td>554.58</td>
<td>282.29</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>7,01,950</td>
<td>486.824</td>
<td>769.182</td>
<td>207.679</td>
<td>976.561</td>
<td>703.04</td>
<td>562.87</td>
<td>283.13</td>
</tr>
<tr>
<td>Increment %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>-0.34</strong></td>
</tr>
<tr>
<td>50+</td>
<td>2005</td>
<td>163,645</td>
<td>578.35</td>
<td>913.793</td>
<td>246.724</td>
<td>1100.51</td>
<td>826.57</td>
<td>668.45</td>
<td>314.22</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>153,676</td>
<td>544.791</td>
<td>860.77</td>
<td>232.408</td>
<td>1093.17</td>
<td>827.08</td>
<td>629.67</td>
<td>314.43</td>
</tr>
<tr>
<td>Increment %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>-5.80</strong></td>
</tr>
</tbody>
</table>
Acknowledgements

- Dr. S.S. Negi, Director, FRI
- Dr. R. K. Aima, Dean, FRI (Deemed) University
- Sri V. K. Dhawan, R. O. Silviculture Division, FRI
- Dr. Rajiv Pandey, Scientist, FRI
OBJECTIVES

1) To examine the growth and biomass productivity of *G. arborea* stands in monoculture and agroforestry practices in different sites
2) To evaluate the productivity of different crops in agrisilviculture system
3) To quantify the carbon and nitrogen allocation patterns in different stands
4) To assess the changes in carbon and nitrogen pools in soils
5) To explore the use of crop residues to manage organic carbon in soil under agrisilviculture system. The results of five year studies on above aspects in *G. arborea* stands are presented.

Introduction

*Gmelina arborea* Roxb., is one among the moderately fast growing indigenous tree, which is greatly encouraged under different social and agroforestry plantations in humid and sub-humid tropics of India for the purpose of timber, fuel and paper pulp production was selected for quantifying the biomass carbon and nitrogen storage. Only limited studies were made to understand the growth and biomass production of *G. arborea* in monocultures and no detailed information is available on agroforestry practices.
**Study sites**

The study was conducted in two sites at Chhattisgarh, Central India.

Site 1:- Forestry Research Farm of Indira Gandhi Agricultural University, Raipur (latitude 21° 12.1' N and longitude 81° 36.1' E)

Site 2:- Kusumi village of Durg district (latitude 21° 76.1' N longitude and 81° 40.1' E).

Mean elevation of the sites ranged from 290-320 m above mean sea level.
The climate of study area is sub-humid tropical with an annual precipitation of 1200-1400 mm.

**Plantation of Gmelina arborea (5 yr-old)**

**Growth of Gmelina arborea stands**

<table>
<thead>
<tr>
<th>Stand type</th>
<th>Age (years)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dhb (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS-AAL</td>
<td>1.99 h</td>
<td>2.81 g</td>
<td>4.76 c</td>
<td>7.25 c</td>
<td>11.88 a</td>
<td>5.73 a</td>
<td></td>
</tr>
<tr>
<td>AS-AAL</td>
<td>1.96 h</td>
<td>2.29 gh</td>
<td>4.50 e</td>
<td>5.44 d</td>
<td>8.63 b</td>
<td>4.52 b</td>
<td></td>
</tr>
<tr>
<td>MS-RLW</td>
<td>1.33 i</td>
<td>2.16 h</td>
<td>3.65 f</td>
<td>4.86 e</td>
<td>6.94 c</td>
<td>3.79 c</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.69 e</td>
<td>2.42 d</td>
<td>4.31 c</td>
<td>5.85 b</td>
<td>9.15 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Height (m)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS-AAL</td>
<td>2.27 i</td>
<td>2.92 g</td>
<td>3.71 f</td>
<td>4.82 e</td>
<td>7.07 a</td>
<td>4.16 a</td>
<td></td>
</tr>
<tr>
<td>AS-AAL</td>
<td>2.24 i</td>
<td>2.52 h</td>
<td>3.63 f</td>
<td>4.47 e</td>
<td>6.62 b</td>
<td>3.83 b</td>
<td></td>
</tr>
<tr>
<td>MS-RLW</td>
<td>1.28 j</td>
<td>2.13 hi</td>
<td>3.37 f</td>
<td>5.34 d</td>
<td>6.13 c</td>
<td>3.65 b</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.81 e</td>
<td>2.53 d</td>
<td>3.57 c</td>
<td>4.87 b</td>
<td>6.61 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Regression models for biomass estimation of different components of G. arborea stands**

<table>
<thead>
<tr>
<th>Biomass Component</th>
<th>Form of the Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf</td>
<td>( Y_1 = a + bD + cD^2 + gDH + e )</td>
</tr>
<tr>
<td>Stem</td>
<td>( Y_2 = a + bD + cD^2 + dD^3 + gDH + e )</td>
</tr>
<tr>
<td>Branch</td>
<td>( Y_3 = a + bD + cD^2 + e )</td>
</tr>
<tr>
<td>Root</td>
<td>( Y_4 = a + bD + cD^2 + gDH + e )</td>
</tr>
<tr>
<td>Total</td>
<td>( Y_5 = a + bD + cD^2 + eH + fH^2 + e )</td>
</tr>
</tbody>
</table>

**Biomass of Gmelina arborea stands**

<table>
<thead>
<tr>
<th>Stand type</th>
<th>Age (years)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total biomass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS-AAL</td>
<td>0.53 h</td>
<td>2.07 g</td>
<td>5.87 e</td>
<td>11.10 c</td>
<td>21.73 a</td>
<td>8.26 a</td>
<td></td>
</tr>
<tr>
<td>AS-AAL</td>
<td>0.41 h</td>
<td>1.10 gh</td>
<td>5.45 e</td>
<td>7.35 d</td>
<td>14.09 b</td>
<td>5.68 b</td>
<td></td>
</tr>
<tr>
<td>MS-RLW</td>
<td>0.13 h</td>
<td>0.84 h</td>
<td>3.72 f</td>
<td>6.09 e</td>
<td>10.38 c</td>
<td>4.23 c</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.36 e</td>
<td>1.33 d</td>
<td>5.01 c</td>
<td>8.18 b</td>
<td>15.40 a</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Carbon (A) and nitrogen (B) concentrations in different components of Gmelina arborea 5-yr-old stands**

<table>
<thead>
<tr>
<th>Plantation</th>
<th>Agrisilviculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A)</td>
<td></td>
</tr>
<tr>
<td>Leaf</td>
<td>0.05 0.10 0.15</td>
</tr>
<tr>
<td>Stem</td>
<td>0.05 0.10 0.15</td>
</tr>
<tr>
<td>Branch</td>
<td>0.05 0.10 0.15</td>
</tr>
<tr>
<td>Root</td>
<td>0.05 0.10 0.15</td>
</tr>
<tr>
<td>B)</td>
<td></td>
</tr>
<tr>
<td>Leaf</td>
<td>0.2 0.4 0.6</td>
</tr>
<tr>
<td>Stem</td>
<td>0.2 0.4 0.6</td>
</tr>
<tr>
<td>Branch</td>
<td>0.2 0.4 0.6</td>
</tr>
<tr>
<td>Root</td>
<td>0.2 0.4 0.6</td>
</tr>
</tbody>
</table>
Forests and Climate change

Intercropping of Linseed under *Gmelina arborea* based agrisilviculture systems

<table>
<thead>
<tr>
<th>Productivity of crops in sole cropping and under <em>Gmelina arborea</em> stands during rainy season</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>SC</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Wheat</td>
</tr>
<tr>
<td>Cowpea</td>
</tr>
<tr>
<td>Urd</td>
</tr>
<tr>
<td>Chickpea</td>
</tr>
</tbody>
</table>

Intercropping of Mustard under *Gmelina arborea* based agrisilviculture system

<table>
<thead>
<tr>
<th>Carbon storage in <em>Gmelina arborea</em> stand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total carbon kg ha⁻¹</strong></td>
</tr>
<tr>
<td>MS-AAL</td>
</tr>
<tr>
<td>AS-AAL</td>
</tr>
<tr>
<td>MS-RLW</td>
</tr>
<tr>
<td>Mean</td>
</tr>
</tbody>
</table>

Nitrogen allocation in *Gmelina arborea* stand

<table>
<thead>
<tr>
<th><strong>Total nitrogen kg ha⁻¹</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>MS-AAL</td>
</tr>
<tr>
<td>Mean</td>
</tr>
</tbody>
</table>

Productivity of crops in sole cropping and under *Gmelina arborea* stands during winter season

| **Crop** | **1. Grain yield (q ha⁻¹)** |
|-----------------------------------------------|
| **3 years** | **4 years** | **5 years** |
| SC | IC | YR (%) | SC | IC | YR (%) | SC | IC | YR (%) |
|--------------------------|----------|--------|--------------------------|----------|--------|--------------------------|----------|--------|--------|
| Wheat                   | 39.5 ± 2.15 | 37.5 ± 2.05 | 5.90 | 41.2 ± 3.45 | 37.2 ± 3.15 | 7.89 | 39.25 ± 2.1 | 36.96 ± 2.4 | 11.71 |
| Linseed                 | 13.20 ± 1.13 | 11.90 ± 0.90 | 9.05 | 12.80 ± 1.1 | 11.40 ± 0.80 | 17.39 | 12.38 ± 2.6 | 10.17 ± 0.9 | 13.85 |
| Mustard                 | 12.10 ± 1.23 | 11.50 ± 0.88 | 4.06 | 12.39 ± 1.0 | 11.35 ± 1.15 | 9.00 | 11.11 ± 0.5 | 9.37 ± 0.72 | 13.8 |
| Chickpea               | 12.20 ± 1.11 | 9.80 ± 0.85 | 10.87 | 12.81 ± 1.1 | 9.90 ± 1.25 | 26.86 | 11.90 ± 0.1 | 9.90 ± 1.2 | 15.70 |

*Intercropping of Linseed under *Gmelina arborea* based agrisilviculture system*
Our studies indicate that *G. arborea* is a suitable tree to be planted in degraded lateritic soils. Although, the growth and biomass production of species was low during initial period, but a significant increase was observed after three years of planting. Growth of *G. arborea* in red lateritic soil was comparatively better than many other indigenous species. The species was also found to be useful for soil amelioration through nitrogen and potassium enrichment in the soil and it even increased the soil pH to a significant level. Phosphorus additions are recommended for lateritic soils to ensure better growth and biomass production.
Sundarban and Global Warming – where lies the threat

Dr Atanu Kumar Raha, IFS
Principal Chief Conservator of Forests, W.B
Head of Forest Forces
The Importance of Sundarban Forest are noted below:-

1) The only mangrove forest of the world having largest floral and faunal diversity
2) The only mangrove forest having a Tiger population
3) Selected as World Heritage Sites, a Ramsar Site (Bangladesh) and a Biosphere Reserve in the Global Network (India)
4) It supports the single largest tiger population in both the countries
5) Home of several endangered, threatened and endemic floral and faunal species
6) A few million people depend on the mangrove forest for livelihood
7) Sundarban mangrove acts as a fish nursery and supports coastal fisheries along Bay of Bengal and Indian Ocean
8) Sundarban forest acts as a sink for the mega-metropolitan pollutants
9) The mangrove forest provides protection to inland habitations against the fury of cyclones

International status of Sunderban

- Sunderban National Park in India is a World Heritage Site (Well protected by Reserved Forest as Buffer all around) declared by UNESCO in 1987
- Sunderban region in India is a Global Biosphere Reserve, recognised by UNESCO in 2001
- Indian Sunderban has been selected for inclusion as Ramsar Site
- Sunderban Tiger Reserve (1973) is part of Project Tiger of GOI

Sunderbans: a transboundary ecosystem

- Sunderbans, a unique mangrove delta, is spread over two countries, i.e., India and Bangladesh
- It is situated along the coast of Bay of Bengal
- The rich floral and faunal diversity and the unique ecosystem has been under threat due to natural and biotic factors
- Though it is a single ecosystem, yet the management perceptions and interventions differ

Sundarban ecosystem

- Mangrove vegetation develops in the estuaries where sweet river water meets the saline water of the sea
- There are 102 islands comprising Indian Sundarban, out of which 54 are habited and balance 48 islands contain mangrove reserved Forest
- Sundarban Reserved forest comprises 4200 sq km, out of which 45% is water
Forests and Climate change

Sundarban and climate change

- "Sea-level rise is the greatest threat and challenge for sustainable adaptation within South and Southeast Asia. A 45 cm rise in global sea levels would lead to the destruction of 75 percent of the Sundarbans mangroves," a UNESCO report warned.

- Along with global sea level rise, there is a continuous natural subsidence in the Sundarbans, causing a rise of about 2.2 mm per year. The resulting net rise rate is 3.1 mm per year at Sagar, the biggest delta of Sundarbans, the report added.

- Underlining that climate change will constitute one of the major challenges of the 21st century; Unesco Director General Koichiro Matsuura in the report has called for "an integrated approach to issues of environmental preservation and sustainable development".

Climate change reconsidered – 2009 Report of NG Int. Panel on Climate Change

- Part of the northern hemisphere that holds lion’s share of hemisphere’s ice, has been cooling for past half century, at a very significant rate, making it unlikely that its frozen water will be released to the world’s oceans

- The studies revealed that the Arctic is still not as warm as it was many centuries ago, when there was much less carbon dioxide and methane in air than there is today

- There is no way … To suggest that a significant increase in atmospheric carbon dioxide would necessarily lead to any global warming, much less than…. predicted by IPCC

When we talk of Sundarban, we must

- Segregate 48 islands, under complete mangrove forest, from 54 islands, totally devoid of forest and thickly populated

- Realize that forested islands are left to nature, whereas populated islands have permanent embankments, 3500 km long, all around them

- Remember that present settlements were established in sundarban, around 250 years back, after cutting down the forests

- Accept that islands in Sundarban are still-growing within a dynamic estuary

Difference of High Tide and Low tide level can be as much as 8m – mud flats appear during low tide on the forest islands

During high tide, much of the forest island goes under water

There are 54 populated islands in Sundarban facing High Tide twice a day – nearly 3500 km long embankment protect 54 islands from the threat of flood everyday, twice a day
The key issues to ponder

- What can be the effect of climate change on floral and faunal diversity
- What can be the effect on the people living in sundarban villages
- Whether sea level rise has perceptibly threatened the home of tiger

The Fauna

Total No of Species = 1586
Vertebrate Spp = 481
Hemichordate Spp = 1
Invertebrate Spp = 1104
Protozoan species = 106

Species included in Sch. I &II of WLP Act
Mammals = 7
Birds = 8
Reptiles = 17

Total species included in Sch. I of WLP Act = 24
Total spp included in Appendix I of CITES Regulation = 14

Floral Diversity- highest amongst the mangroves of the world

- True Mangrove species = 26
- Mangrove associates = 29
- Back mangrove species = 29
- Family = 40  Genera = 60
Total Species = 84

Pneumatophores – the breathing roots adapting to increased salinity in soil

Rhizophora species – stilt roots to support the water pressure during submergence

Nypa spp – a sweet water loving plant gradually vanishing due to increasing salinity in Indian Sunderban – but why this increasing salinity?
Saline blanks appear in mangrove islands

Tiger prawn seed collection damages aquatic biodiversity as well as embankments

Fishing is the second largest occupation of the fringe villagers. Fishing is controlled and not allowed within Protected Areas.

Socio-economic status of fringe population

- There is no human habitation in 4260 sq km of R.F in Indian part.
- Along the northern and north-western fringes of Indian Sunderban, around 4.1 m people live. The figure is around 3.5 m for Bangladesh. A large no of fringe people depend on Sunderban for subsistence.
- Large percentage of population is Below Poverty Line.
- Due to non-availability of sweet water, except in monsoon, agriculture is mono-cropping, which is also primary occupation of 90% of population.
- Second most important occupation is fishing, either in R.F. water or in the sea.
- Due to lack of industries, employment opportunities are poor.

Nearly 4.1 million people live in the non-forest zone of SBR-around 0.22 million living in 66 mouzas within 2 km buffer zone.
1st Indian Forest Congress - 2011

Using GPS for Ground Truth Verification of Satellite Data

Saline Blanks in areas not inundated by High tides

Chlorophyll monitoring in Sundarban estuary

Erosion and accretion are natural processes in a developing estuary like Sundarban

Time series change study of Mayadwip island

Jambu Island in Sunderban as in 1989

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Forests and Climate change

Encroachment at centre of forested island

Encroachment grows and island erodes

More than 200 ha cleared by Mar 2001

In July 02, encroachers removed and blanks planted

Time series analysis of Jambudwip

GIS analysis of island dynamics

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Monitoring accretion and afforestation in remote areas

Satellite imagery of 1973

Satellite Imagery of 1981

IRS 1C satellite data showing status of Ghoramara in 2001

Satellite image of 2005

Satellite image of 2009

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Forests and Climate change

Satellite imagery 2009

Satellite imagery 2001

Eco-Development and JFM activities

Producing dry chilli powder - income for EDC members

Sunflower cultivation in winter with stored rain water

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Sundarban – the real threats conveniently forgotten

- the present trend of reduced fresh water flow in Indian Sundarban due to construction of dams/barrages upstream
- Arresting the process of formation of populated islands by constructing embankments
- Tremendous biotic pressure on forest biodiversity from the forest fringe population
- Present Sundarban, hardly six thousand years old, is a geologically sinking delta
- A tectonic tilt in this part of Bengal, hundreds of years ago, had shifted the sweet water flow more towards Bangladesh Sundarban

What is feasible to counter the threats

- To control further increase in population within and around the estuary
- To harvest rain water for providing multiple cropping in villages
- Discourage drawal of ground water which threatens sinking of the inhabited islands
- Provide alternate sustainable livelihood in villages to reduce biotic pressure on Sundarban forests
- Generate awareness and involve local people to prevent poaching of deer/tiger in the forest and conserve floral and faunal diversity

Sundarban – an example of natural adaptation

- Due to increased salinity in Indian sundarban water, more salt-tolerant species predominate Indian Sundarban
- The saline blanks are gradually getting vegetated with highly salt-tolerant species like *Ceriops decandra*
- Tigers, deer drink saline water only in Sundarban
- Wild animals have adapted to the daily rise of water level by 10 to 15 ft everyday, twice a day

Sundarban - A thought for all

- Global warming is a reality and global phenomena
- An act of mis-deed elsewhere in the world will un-do all the good works done in Sundarban
- If Sundarban goes under water, Kolkata, Mumbai, Holland, NuYork and similar others will also go under water

Members of EDC attending micro-planning meeting

Training of women SHG in zari work
Your intelligence has threatened our home – show your wisdom to save us

Your home is protected by Embankments and unsafe, but our home is safe if you don’t interfere
Global Warming is defined as the increase of the average temperature on Earth. As the Earth gets hotter, disasters like hurricanes, droughts and floods become more frequent.

For millions of years trees kept Earth from overheating by absorbing carbon dioxide. Fossil fuels have overwhelmed this natural carbon cycle.

CO2 capture systems that look like trees? Aren’t real trees doing their job? They do their job. But their job is not to clean up after our CO2 emissions and they are not really designed to do that for two reasons: One is that a tree spends most of its effort converting that CO2 into biomass; the other is that it is biomass which you still have to store.

If you wanted to collect all the CO2 we produce by using biomass growth, which could be trees or corn, you would roughly be talking about using all the agricultural land available globally.

Global Warming is defined as the increase of the average temperature on Earth. As the Earth gets hotter, disasters like hurricanes, droughts and floods become more frequent.
Forests and Climate change

Insects comprise 54% of all known species and occupy every terrestrial habitat (Schowalter 2000), so exploring the responses of insects to climate change will provide us with a good understanding of how climate change is affecting biological systems.

Projections from the UN climate change body the Intergovernmental Panel on Climate Change (IPCC) say that global surface temperature will probably rise a further 1.1 to 6.4 degrees Celsius (2.0 to 11.5 degrees Fahrenheit) during the 21st century.

Concerns - Possibility of drought and climate change
[making the trees more susceptible to an insect that is not native to that habitat, have been expressed by the scientific community].
Under pressure from human encroachment, the planet’s forest cover has had to cope with insect invasions too.
Global warming, it appears, has not only increased tree pests’ resistance levels, but also led them to thrive and wipe out entire forests in a span of a few months.

Last 100 years,
( the average air temperature near the Earth’s surface has risen by a little less than 1 degree Celsius, or 1.3 degrees Fahrenheit)

Doesn’t seem that much, does it?

Yet this warming is responsible for the conspicuous increase in storms, floods and raging forest fires.

Their data show that an increase of one degree Celsius makes the Earth warmer now than it has been for at least a thousand years.
The top 11 warmest years on record were all in the previous 13 years, said NASA in 2007, and the first half of 2010 has already gone down in history as the hottest ever recorded.

Vast research [last two decades]
Understand how these human-induced changes in climate have affected individual species and communities and will do in the near future.

Consequently, we have started to gain significant evidence of the ecological impacts of current warming on a broad range of organisms with diverse life-history traits and geographical distributions.

What do forests do?
Forests ---- use solar energy to perform photosynthesis transforming carbon dioxide and water into sugar, which stores the solar energy.

Not just that, they also act as filters of carbon dioxide and reduce the amount of energy or heat the planet radiates into space.

This helps lock the heat on earth. But, when trees are felled or burned, the carbon dioxide they store, escapes back into the air.

As the concentrations of these gases increases, the earth’s temperature also goes up, making the planet’s surface warmer.

Spring comes early for bees
vast research [last two decades]
Understand how these human-induced changes in climate have affected individual species and communities and will do in the near future.

Consequently, we have started to gain significant evidence of the ecological impacts of current warming on a broad range of organisms with diverse life-history traits and geographical distributions.

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[ 763 ]
Why should we expect an effect of climate change on insects?

- Insects (groups of organisms) are most likely to be affected by climate change because climate has a strong direct influence on their development, reproduction, and survival.
- Moreover, insects respond quicker to climate change than long-lived organisms, such as plants and vertebrates.

The fossil record provides good evidence:

Insects have responded to past changes in climate

- Beetle remains clearly illustrate that species shifted their geographic ranges during the Quaternary in response to the glacial/interglacial climatic oscillations (Coope 1995).
- Several carabid species living today only in the boreal regions of Europe were present in the British Isles when the ice sheets covered most of northern and central Europe.
- Conversely, many dung beetle species restricted today to the south of Europe were living in the British Isles during the thermal maximum of the Last Interglacial, when the climate of Britain was considerably warmer than it is today (Coope 1995).

Species responses are expected to be idiosyncratic depending on the flexibility of different life-history characteristics

Warming

[potentially affects several aspects of insect life-cycle and ecology, especially those directly controlled by energy availability variables such as degree day (ac-cumulative temperature needed for development)]

Consequently, potential responses include changes in phenological patterns, changes in habitat selection, and expansion and contraction of geographic and altitudinal ranges.

Bale et al. (2002) proposed:

Different growth rate and diapause requirements may influence distributional responses to climate change

- Fast growing- [non-diapausing species or those which are not dependent on low temperature to induce diapause] will respond to warming by expanding their distributions.
- In contrast, slow growing species which need low temperatures to induce diapause (such as boreal and mountain species in the northern hemisphere) will suffer range contractions.

Thus, climate change will affect species ranges, with expansion in some species and contractions in others, which in turn will lead to changes in regional and local diversity.

Best documented responses to recent climate change

- Phenological changes are probably the best documented responses to recent climate change and have been detected for a wide range of organisms from plants to vertebrates (Root et al. 2003, Root & Hughes 2005).
- With rise in temperature, insects will pass through their larval stages faster and will become adults earlier.

Thus, observed responses include both an advance in the timing of adult emergence and an increase in the length of the flight period.

<< Back to contents
Forests and Climate Change

In this regard:

**Lepidoptera** are by far the best documented group

Changes in butterfly phenology have been reported in the UK (Roy & Sparks 2000), with species advancing their flight periods by around 2–10 days for every 1°C increase in temperature. This has resulted in an extended flight period, especially for multivoltine species.

In Spain butterflies have advanced their first appearance between one and seven weeks in a period of 15 years (Stefanescu et al. 2003) and by around eight days per decade in California (Forister & Shapiro 2003)

[In both cases phenological changes were correlated with the amount of warming experienced during the same time period].

Although evidence for other groups of insects is rare, this is probably due to a lack of data more than to a lack of response.

Gordo & Sanz (2003) observed a common phenological response in four unrelated species of insects (a butterfly, a bee, a fly and a beetle)

During the last 50 years all four species showed significant temporal changes in their first appearance date. In all cases their appearance earlier in the year was correlated with the increase in spring temperature observed in the area during the same time period.

**Distributional shifts**

Climate is an important determinant of geographic range for many species (Andrewartha & Birch 1954)

Consequently warming is expected to force species to shift their distributions by expanding into the new climatic areas and by disappearing from areas that have become climatically unsuitable (Hughes 2000)

Shifts in distributions will occur, in part, by range expansion at the cool, upper altitudinal and latitudinal limits

and

by contractions at the warm, lower altitudinal and latitudinal limits of species' ranges. Numerous cases of recent distributional shifts have been recorded for a variety of taxa from around the world (Pounds et al. 2005, Wilson et al. 2005,)

**Several species of Microlepidoptera** in The Netherlands (Ellis et al. 1997) and **Odonata** in the UK (Hassall et al. 2007) have also experienced considerable temporal shifts in their phenology earlier in the year.

**Aphids** are another group for which long term datasets are available (due no doubt to their agricultural importance as pests).

Early adult emergence and an early arrival of migratory species have been reported in the UK for this group (Zhou et al. 1995, Harrington 2007).

Thus phenological responses are likely to be widespread within all groups of insects

especially at higher latitudes and elevations where temperature has increased and is predicted to increase more than in other parts of the world (Houghton et al. 2001)

There are not enough data yet to prove these predictions because information on phenological changes from different latitudes (especially southern and tropical areas) and from different altitudes is not available.

However, Parmesan (2007) reported a significant increase in the strength of advancement of spring events in the northern hemisphere with increasing latitude, although latitude explained only 4% of overall variation of phenological changes.

**Climate Change**

[Increase in mean temperature- Changes in precipitation- Frequency of extreme weather events]

1. **Changes in Phenology:** Early spring occurrence- Extended flight period- Multivoltinism
2. **Changes in distributions:** Expansions northward and uphill- Southward and downhill contractions
3. **Evolutionary process:** Changes in Species interactions- Insect-host plant- Host-parasitoid - Competition- Decoupling of mutualism
4. **Further shifts in distributions**
5. **Extinction of some species**
6. **Changes in Biodiversity and Community composition:** Loss of local and regional diversity-
7. **Progressive dominance of generalist species**
Understanding the effects of rapid climate change on ecosystems and species is an important goal of modern ecological research.

Increased unpredictability and variability in regional climates, particularly with regard to precipitation, should be exceptionally disruptive:

1. Models of climate change have predicted greater frequency and duration of droughts in some areas.
2. Increased periods of high precipitation in others and
3. A widespread increase in the frequency of extreme weather events.

Recent studies of forest insects have linked population outbreaks to phenological changes in insect life histories brought about by global climate change. Such analyses have predicted increased frequencies of outbreaks and longer durations of outbreaks.

Climate change can also affect insects in indirect ways, where the insect responds to climate-induced changes mediated by other factors. These other factors may include interaction with other species (competition, predation and parasitism) or for herbivorous insects, host plant

Finally, warming may affect the structure of existing communities because individual responses will inevitably alter species interactions, leading to changes in the composition of natural communities

Pest outbreaks can contribute either directly or indirectly to economic and environmental losses and have adverse effects on tree growth.

Insect outbreaks are expected to increase in frequency and intensity with projected changes in global climate through direct effects of climate change on insect populations and through disruption of community interactions.

The pests that affect trees in India

**Defoliator** - Calopepla leayana (Chrysomelidae) Gmelina arborea
**Bud shoot feeder** - Dioctria sp. (Pyralidae) Pinus sp.
**Defoliator** - Hybloeoa puera (Hybloeidae) Teak
**Defoliator** - Eutectona machaeralis (Pyralidae) Teak
**Wood borer** - Hoplocerambyx spinicornis (Cerambycidae) Shorea robusta
**Bud shoot feeder** - Hypsipyla robusta (Pyralidae) Mahogany
**Sap feeder** - Tingis beessoni (Tingidae) Gmelina arborea
**Wood borer** - Xyleutes ceramica (Cossidae) Teak, Gmelina
**Wood borer** - Xystocera festiva (Cerambycidae) Paraserianthes falcataria
**Gall inducer** - Leptocybe invasa (Eulophidae) Eucalyptus
**Subterranean** - Termites (Termattidae) Eucalyptus

Climate change indirectly affect the forest ecosystems through the activity of phytophagous insects

**FOR INSECTS**

1. Increased CO2 levels in the atmosphere may cause the C/N balance in the plant tissues to shoot up, which results in a lower food quality for many defoliating insects.
2. Some insects respond by increasing the level of leaf consumption and consequently the damage to the tree, whereas others show higher mortality and lower performance.

Temperature rise can also alter the mechanism by which the insects adjust their cycles to the local climate (diapause), resulting in faster development and higher feeding rate. This has been exhibited by the spruce web-spinning sawfly outbreaks in the Southern Alps.

Climate change can also affect insects in indirect ways, where the insect responds to climate-induced changes mediated by other factors. These other factors may include interaction with other species (competition, predation and parasitism) or for herbivorous insects, host plant
In India, an increase in the destruction of forests has made forest managers analyze and compare the percentages of national forest cover lost to pest and disease problems over a period of time.

GALL INSECT [Leptocybe invasa]

Says Dr Manimekalan, an assistant professor at the department of entomology, Bharatiar University, “Various teams have been conducting surveys in Tamil Nadu, Kerala and Andhra Pradesh to assess the damage in nurseries and plantations. Experts have also made field visits to study the damage of eucalyptus plantations in Andhra Pradesh and the gravity of the pest problem.”

Scientists are of the opinion
Natural forests usually have their own control mechanisms to fight such infestations. “In natural forest, the pest effect is not much because nature takes care of the insects. It is the plantation areas that bear the brunt,” says Dr Manimekalan.

But some feel
Greenhouse gas emissions, especially from smokestacks, vehicles and burning forests, contribute to global warming in a big way. So, blaming insects for deforestation is rather unfair. Vouching for this theory is Dr Mohammed Shafi.

“Scientists believe that insects and pests are not the real culprits; they cannot be blamed needlessly. Compared to the enormous destruction mankind causes to the ecosystem, their contribution is negligible. These poor insects are blamed unnecessarily, when it is the global emissions that have caused warmer planets.”

Most dangerous insects are defoliators (needle-gnawing and leaves-gnawing) category.

Coniferous forests are most sensitive to attacks from needle-gnawing insects. Pests of cones, fruits and seeds are also a threat to forest seed plantations, since they decrease the yield, quality of seeds, their germinating capacity and energy.

Of the pests in young forests and nurseries, the most dangerous are two species of cockchafer (Family Scarabaeidae) – east (Melolontha hipocastani) and west (M melolontha).

The cockchafer has been disastrous for forests

Death of trees severely disrupts the forest ecosystem and causes catastrophic losses as well.

Insects and diseases are integral components of forests outbreaks can have adverse effects on the growth of trees and their survival and also affect global temperatures in the long run, in addition to hitting the food chain.

kinds of problems by insects and diseases, often interlinked, have changed rapidly in recent years.

The main concern across the globe is the larvae from insects, which though native to one country, have now invaded forests across the globe following the change in temperatures, which helps them multiply.

The trees bleed sap and eventually die.

Gall wasp first observed in 2004 at Marakkanam, Tamil Nadu.

[The invasive wasp effect has been more severe in eucalyptus plantation and nurseries in Tamil Nadu, Karnataka, Kerala and Andhra Pradesh]

Earlier it was an insect of South India
ICFRE INSTITUTES - The Institute of Forest Genetics and Tree Breeding and Tropical Forest Research Institute has been doing extensive research in this area and has reported the presence of gall-making insects in eucalyptus and alerted various state forest departments, forest corporations, wood-based industries and farmers.

But recently this insect has migrated to North India also and work has been taken on war footing in Forest Research Institute also.

In Asia, the Siberian eggar (Dendrolimus sibiricus superans) envelopes large areas and causes high level of mortality of dark coniferous species.

Insect pell-mell
1. The tiny bark beetle – that has decimated millions of acres of pine forest from British Columbia down to New Mexico is considered to be the largest insect infestation in North American history.

2. The cerambycid beetles - also transmit nematodes, fungi and other pathogens can kill the host trees. They are also likely to transmit pitch canker and other fungal diseases. The tunnels made by cerambycid larvae destroy the vascular tissues of the tree, killing the entire tree.

3. In the US, the beetles target the maples, horse chestnuts, black locusts, elms, birches, willows and poplars. They have infested thousands of trees in New York and Chicago. To eliminate the beetles, cutting of infested trees and destroying them are the only effective means.

According to FAO figures, 13 million hectares of forests worldwide are lost every year, almost entirely in the tropics. Deforestation remains high in Africa, Latin America and Southeast Asia.

In Asia, the Siberian eggar (Dendrolimus sibiricus superans) envelopes large areas and causes high level of mortality of dark coniferous species.
Challenges of Joint Forest Management and Green India Mission

Dr Dharmendra Verma, IFS

Green India Mission (GIM)
- One of the Eight Missions under National Action Plan on Climate Change (NAPCC)
- GIM Aims to achieve:
  - 43 million tonnes of CO₂ sequestration annually
  - Eco restoration of 10 m ha of forests in 10 years (5 m ha within forest estate and 5 m ha outside the forest estate)
  - Enhance forest based livelihoods of 3 million households dependent on forests
  - Forest Department- Local communities
    - Co-management (JFM)
  - Outlay Rs 46,000 Crore for 10 years

Forest Management in India
- Strong institutional support mechanism
  - Strong policy framework
    - NFP, 1988
  - Strong legislative mechanism
  - Strong planning base
    - Five Year Plans, State Planning, NFAP
  - Strong organisational structure
    - MoEF, SFDs, FDCs
  - Specialized Institutional base
    - Research Organisations
      - ICFRE, SFRI
    - Training Organisations
      - IGNFA, DFE
Opportunities of Co-Management in India

- Substantial forest area under co-management
  - 106,000 JFMCs working in the country
  - Covering about 22 million ha of forestland
    - (about one-third of total forest cover)
  - Democratization of government functions
  - Rural infrastructure and employment increased
  - Large scale assets created under FDA-JFMC mechanism
  - About Rs 2000 crore invested through FDA mechanism since 2002
  - JFM has contributed towards empowerment of local communities
  - Although linkage of JFM with PRI needs clarity

Challenges of Forest Management in India

- Increase of forest cover to 33% of GA
  - Not achieved though gain are being made
  - Best case scenario predicts forest cover from 23% in 1997 to 26.6% by 2020
  - Business as usual predicts it at 23.9% by 2020
  - Perhaps a need to revisit the same in view of land availability in the productive zone
  - World forest cover average 30%
  - Per capita forest, India = 0.07 ha, World = 0.64 ha

- Increase of forest stocking
  - Stocking remain low (78/58 m3 per ha) as compared with world average (131 m3 per ha)
  - Productivity remain low (0.7 m3 per ha per year) as compared with world average (2.1 m3 per ha per year)

- Forest Product Supply: Bridging the Gap
  - Timber availability (Base yr 2004)
    - Demand rising, currently about 74 m3
    - Supply stagnant at 40 m3
    - Gap about 34 m3
    - Gap met through imports, causing unrecorded removals
  - Fuelwood availability (Base yr 2006)
    - 40% of energy needs met from forests
    - Demand rising, currently about 270 m tonnes
    - Supply stagnant, about 102 m tonnes
    - Gap about 170 m tonnes
    - Gap met through unauthorized removals, causing forest degradation
  - Fodder availability (Base yr 2002)
    - 30% of fodder needs met from forest
    - Demand 1337 m tonnes
    - Supply 972 m tonnes
    - Gap 365 m tonnes
    - Causing forest degradation

Opportunities of Co-Management in India

- Afforestation: Raising man made forests
  - 32.6 million hectares planted by 2000
    - 45% of the area planted by fast growing species
    - 8% teak, 10% pines and conifers, rest misc
    - 8 million hectares in private, communal and non forestland
  - 50% of plantations since 1980 are in agro-forestry environment
  - Annual planting rate 1.51 m ha during 1990-2000
  - Private planting exceeding public planting
    - 0.56 m ha rubber plantations
## Challenges of integrating JFM and GIM

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance forest productivity</td>
<td>Meeting timber, fuelwood, NTFP requirements</td>
</tr>
<tr>
<td>Increase stocking of forests</td>
<td>Increase carbon sink</td>
</tr>
<tr>
<td>Biodiversity conservation in natural forests</td>
<td>To act as reservoir of gene pool and meet diverse local needs</td>
</tr>
<tr>
<td>Ecological functions of forests</td>
<td>Management of water and soil regime, nutrient recycling</td>
</tr>
<tr>
<td>Meeting local needs</td>
<td>Forest products, employment and poverty alleviation initiatives</td>
</tr>
<tr>
<td>Decentralised forest management</td>
<td>Next generational issues of JFM need to be addressed. E.g., benefit sharing, capacity building, leadership, institutional sustainability, linkage with development schemes like MNREGA</td>
</tr>
<tr>
<td>Forest leadership to address challenges of the sector</td>
<td></td>
</tr>
</tbody>
</table>

## Conclusion: Way Forward

- Prioritisation of forest management objectives by suitable mix of:-
  - Production Forestry
  - Conservation Forestry
  - Rural Development Forestry
- Management process from command and control to participatory
- Forest planning to be strategic and landscape based
- Modernise and innovate in management procedure, silviculture, technologies, and research
- Skill upgradation of forestry personnel and JFMC
- Introduce pluralism in forestry personnel with functional specialisation
- Forestry extension on a large scale
  - Area, people, technology
Silvicultural Challenges and Opportunities for Green India Mission

Dinesh Kumar and Anita Tomar¹

Forest Research Institute, Dehradun
¹Centre for Social Forestry and Eco-Rehabilitation, Allahabad

Green India Mission

Some key points
- Quality improvement of 5 million ha forest area and creation of additional 5 million ha tree/forest cover
- Departure from traditional afforestation programmes of the past
- Achieving 50-60 million tonne annual carbon sequestration requires use of fast-growing species

Challenges
- Difficult choice of species for underplanting/gap filling
  - Light intensity available in stand
  - Species
  - Age or tree size
  - Density
  - Tolerance to shade
  - Allelopathy
  - Growth rate
  - Utility

Inadequate experience of researchers and managers in mixed planting

Underplanting and planting in mixture would require very careful selection of species.
It is often seen that involvement of locals in plantation planning is limited only up to deciding what species should be planted, the bigger issue of how many plants of each species should be planted, is largely decided by officials of implementing agencies alone depending upon their convenience.

What Should Be Done?

- Difficult choice of species for underplanting/ gap filling?
  - Can be worked out with field surveys

- Inadequate availability of planting material?
  - Ask researchers for species-specific information/solution

- Planting operation
  - Demarcation of smallest unit of land (area with one labourer) on ground with GPS reading for better monitoring and incentives to better performers
    - Use of rectangular/square plots as far as possible
  - Payment on basis of numbers planted (rather than manday)
    - Pre-planting inventorisation of seedlings
    - Post-planting inventorisation

- Inadequate availability of planting material
  - Availability of seed and cuttings, especially superior material (tree, shrubs, herbs)
  - Techniques for nursery, planting and aftercare of several species

- Inadequate trained manpower

- Training of workers at ground level as well as supervisors
  - Prefer local youth; provide basic training and some exposure

- Transparency in execution of all activities to face any audit or RTI query.
  - Unique ID, PAN Number, voter ID, etc.
  - Data must be fully computerised.
  - Modern means of communication: Website, email, SMS; all potential workers must easily get information about jobs in forestry activities regularly irrespective of their nearness to forest officials.

- Research support must be provided to the Mission’s execution on priority
  - Immediate research solutions
  - Long-term studies

- Avoiding contractors or middlemen
- People’s estimate - Demystification of the technical detailed estimate. Apart from technical part, there must be simple estimate for layman to ensure transparency and accountability.
- Work identified and approved by village institutions.
- All works sanctioned with physical/technical/financial details in public domain (notice boards/web).
- Preventing bogus records and payment of wages below prescribed levels
- Social audit as well as independent verification and monitoring by external agencies at various steps of implementation of activities
- Lessons from similar programmes e.g. MNREGA, JFM etc must be put to use
Going Green Computing - An ecological perspective to reduce carbon footprint in forestry organizations

R.VIVEKANANDAN
IFGTB, COIMBATORE

Green IT

- Green IT refers to environmentally sound IT, and is the study and practice of designing, manufacturing, using, and disposing of computers, efficiently and effectively with minimal or no impact on the environment (Murugesan2008).

Information Technology Ecosystem

- Similar to Biological ecosystems, Information technology (IT) has evolved its own “ecosystem,” in which the output of one component serves as the input of another component.
- IT Ecosystem (ITE): Computers System Hardware, Telecommunications/Networks, Embedded Systems, and the Software which makes them all work.
Green strategies

- Reducing carbon emissions from large data centres by Optimization of energy consumption.
- Server and storage virtualization
- Using alternative energy resources
- Procurement of environmentally friendly ITE Components (PCs and servers, networking, embedded systems etc.)
- PC power management
- Leverage on technologies like telecommuting and telepresence

Green strategies

- Increasing video conferencing to reduce travelling
- Responsible management of e-waste, businesses to reduce carbon footprint.
- Global position systems, radio frequency identification, Web services, unified communications, next-generation broadband, wireless, smart urban infrastructures, and other new integration technologies make it possible for organizations to become eco-friendly. (V.C Gopalratnam)
The total CO2 emissions from the global cloud were estimated to be about 820 million tons in 2007, and are projected to rise sharply to 1430 million tons by 2020 (Green Peace 2010).

Nevertheless, it is likely better for the environment if several clients use an efficient cloud data centre instead of inefficient independent data centres.
Conclusion

- Information technology is clearly very advantageous for humans, and helps us accomplish many activities more effectively and efficiently.
- IT, if used without consideration of the environment, however, can result in devastating consequences to the very natural systems that support life on this wonderful planet.
- Solutions such as virtualization, cloud computing, better and more efficient cooling practices in data centres, policy changes in organization, environment friendly government regulations will contribute to minimizing the environmental damage due to the fast growing global demand for IT.

References

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- Subhash (Sam) S. Valanju, Green Computing is the Utmost Requirement, Silicon India, September 2008
Carbon Sequestration Potential of Biomass under different agroforestry land use systems in Poanta area of Himachal Pradesh

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Indian Forestry Congress 2011
New Delhi India
Indian Council of Forestry Research and Education (ICFRE)
Ministry of Environment and Forests

Presented by
Bilal Ali Khaki
PhD. Research Scholar Silviculture Division FRI Dehradun

INTRODUCTION

Global climate change, caused by increased emission of greenhouse gases (GHGs) is likely to affect the agro-ecosystems.

In agroforestry systems carbon sequestration is a dynamic process and can be divided into phases. At establishment, many systems are likely to be source of GHGs.

These follow a quick accumulation phase and a maturation period when tonnes of carbon are stored in boles, stems, and roots of trees and in soils.

At the end of rotation period, when the trees are harvested and land returned to cropping (sequential systems), part of carbon will be released back to atmosphere (Dixon, 1995).

In case of simultaneous systems like hedgerow inter-cropping, silvi-pasture systems and agri-silviculture systems fate of carbon will be different.

Therefore, effective sequestration can only be considered if there is a positive net carbon balance from an initial stock after a few decades (Feller et al., 2001).

Study Area
The present investigation was conducted during January-June 2007. Poanta valley is located at an elevation of 350 m asml. It is on the western extreme of the Doon Valley distance of about 55 km from Dehradun.

Locality factors of the study area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>30° 26’ N</td>
</tr>
<tr>
<td>Longitude</td>
<td>77° 37’ E</td>
</tr>
<tr>
<td>Altitude</td>
<td>1278 (feet), 388 (m)</td>
</tr>
<tr>
<td>MAT</td>
<td>21.3°C</td>
</tr>
<tr>
<td>MAP</td>
<td>1250 mm</td>
</tr>
<tr>
<td>Soil type</td>
<td>Brown hills &amp; alluvial group</td>
</tr>
<tr>
<td>Texture</td>
<td>coarse</td>
</tr>
</tbody>
</table>
Material and Methods

Six agroforestry systems were selected viz.  

<table>
<thead>
<tr>
<th>Agroforestry system type</th>
<th>Code</th>
<th>Tree crop combination</th>
<th>Net cropped area m²</th>
<th>Area under trees m²</th>
<th>Area under grasses m²</th>
<th>No. of trees/hectare</th>
<th>Age of the land use system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hortipastoral</td>
<td>HP</td>
<td>Mango + Litchi + natural grasses</td>
<td>-</td>
<td>1000</td>
<td>9000</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>Silvopastoral</td>
<td>SP</td>
<td>Eucalyptus + natural grasses</td>
<td>-</td>
<td>1300</td>
<td>8700</td>
<td>400</td>
<td>12</td>
</tr>
<tr>
<td>Agrisilviculture</td>
<td>AS</td>
<td>Sal + wheat</td>
<td>9000</td>
<td>1000</td>
<td>-</td>
<td>-</td>
<td>60</td>
</tr>
<tr>
<td>Hortisilvipastoral</td>
<td>HSP</td>
<td>Mango + Litchi + natural grasses</td>
<td>-</td>
<td>1400</td>
<td>8600</td>
<td>144</td>
<td>12</td>
</tr>
<tr>
<td>Pure forest</td>
<td>PF</td>
<td>Sal</td>
<td>-</td>
<td>10000</td>
<td>-</td>
<td>200</td>
<td>40</td>
</tr>
<tr>
<td>Natural grassland</td>
<td>NG</td>
<td>-</td>
<td>-</td>
<td>10000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Branch Biomass

Total numbers of branches irrespective of size were counted on each of the sample tree, then these branches were categorized on the basis of basal diameter into three groups viz  6 cm, 6-10 cm, and >10 cm. Fresh weight of two sampled branches from each group was recorded separately. The following formula (Chidumaya, 1990) was used to determine the dry weight of branch.

\[ B_{dd} = \frac{B_{fs}}{1 + M_{cb}} \]

Where \( B_{dd} \) - oven dry weight of branch, \( B_{fs} \) - fresh/green weight of branches, \( M_{cb} \) - moisture content of branch on dry weight basis.

Leaves from the branches were removed, weighed and oven dried separately to a constant weight at 80 ± 5°C (Chidumaya, 1990).

Leaf biomass

Leaves from the branches were removed, weighed and oven dried separately to a constant weight at 80 ± 5°C (Chidumaya, 1990).

Below ground biomass of roots was calculated by multiplying the above ground biomass by a factor of 0.26 (Cairns et al., 1997).

Results

<table>
<thead>
<tr>
<th>Land use systems</th>
<th>Above ground carbon (Tonnes ha⁻¹)</th>
<th>Below ground carbon (Tonnes ha⁻¹)</th>
<th>Total carbon (Tonnes ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hortipastoral system (HP)</td>
<td>6.86</td>
<td>2.41</td>
<td>9.28</td>
</tr>
<tr>
<td>Silvopastoral system (SP)</td>
<td>14.72</td>
<td>5.17</td>
<td>19.89</td>
</tr>
<tr>
<td>Agrisilviculture system AS</td>
<td>15.32</td>
<td>5.38</td>
<td>20.70</td>
</tr>
<tr>
<td>Hortisilvipastoral system (HSP)</td>
<td>8.19</td>
<td>2.88</td>
<td>11.07</td>
</tr>
<tr>
<td>Pure forest (F)</td>
<td>60.38</td>
<td>21.22</td>
<td>81.60</td>
</tr>
<tr>
<td>Natural grassland (NG)</td>
<td>1.54</td>
<td>0.46</td>
<td>2.01</td>
</tr>
</tbody>
</table>

The data presented in table evinced that the maximum above ground biomass (134.18 tonnes ha⁻¹) was produced by pure forest (Sal) which was found to be significantly higher than the all other land use systems.

Carbon stock under different land use systems (Tonnes ha⁻¹)

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<td>0.46</td>
<td>2.01</td>
</tr>
</tbody>
</table>

Stem biomass

To estimate stem biomass of all the trees falling in the plot (10 x 10 m) were enumerated. The diameter at breast height was measured with caliper and height with Ravi’s multimeter. Form factor was calculated with Spiegel Relaskope to find out the tree volume using the formula (Smith, 1954)

\[ V = \frac{2 \times B_{h} \times h}{3} \]

Where \( f \) - Form factor

\( b_{h} \) - height at which diameter is half of dbh

\( h \) - Total height

Specific gravity

The stem cores were taken to find out specific gravity which was used further to determine the biomass of the stem using maximum moisture method (Smith, 1954)

\[ G_{i} = \frac{G_{s} \times M_{s}}{M_{i}} + \frac{1}{G_{s}} \]

Where,

\( G_{i} \) - specific gravity based on gross volume
\( M_{s} \) - weight of saturated volume sample
\( M_{i} \) - weight of oven dried sample

\( G_{s} \) - average density of wood substances equal to 1.53
The results obtained revealed the biomass production level both below and above ground was highest (181.34 tonnes ha⁻¹) in Pure forest system whereas minimum (4.47 tonnes ha⁻¹) in natural grassland. Agrisilviculture system produced the second highest biomass level among the different systems despite having less number of trees (60 tonnes ha⁻¹) over silvi-pastoral system which contained 400 numbers of trees per hectare. The CO₂ mitigation was highest in pure forest system (297.84 tonnes ha⁻¹) followed by Agri-silviculture system, Silvipastoral system, Horti-silvipastoral, Hortipastoral, Natural grassland. The minimum value was in natural grassland system.

<table>
<thead>
<tr>
<th>Land use systems</th>
<th>CO₂ mitigation levels (Tonnes ha⁻¹)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above ground</td>
<td>Below ground</td>
</tr>
<tr>
<td>Hortipastoral system (HP)</td>
<td>25.03</td>
<td>8.79</td>
</tr>
<tr>
<td>Silvipastoral system (SP)</td>
<td>53.7</td>
<td>18.87</td>
</tr>
<tr>
<td>Agrisilviculture system</td>
<td>55.91</td>
<td>19.63</td>
</tr>
<tr>
<td>Hortisilvipastoral system (HSP)</td>
<td>29.89</td>
<td>10.51</td>
</tr>
<tr>
<td>Pure forest (F)</td>
<td>220.38</td>
<td>77.44</td>
</tr>
<tr>
<td>Natural grassland (NG)</td>
<td>5.621</td>
<td>1.67</td>
</tr>
<tr>
<td>SE ±</td>
<td>5.45</td>
<td>3.10</td>
</tr>
<tr>
<td>CD₉₅</td>
<td>12.13</td>
<td>6.90</td>
</tr>
</tbody>
</table>

**Conclusions**

- The results obtained revealed the biomass production level both below and above ground was highest (181.34 tonnes ha⁻¹) in Pure forest system whereas minimum (4.47 tonnes ha⁻¹) in natural grassland.
- Agrisilviculture system produced the second highest biomass level among the different systems despite having less number of trees (60 tonnes ha⁻¹) over silvi-pastoral system which contained 400 numbers of trees per hectare.
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A STUDY ON GROWTH PERFORMANCE OF SELECTED TREE SPECIES IN VERMICOMPOSTED COAL MINE SOILS IN JHARKHAND, INDIA

Dr. M.V. Durai
Institute of Forest Productivity
Ranchi (Jharkhand)
Email: duraimv@gmail.com

4ha destroyed for 1tonne coal (Ghosh 1990)
Coal industry accounts 1400ha unproductive land/yr in 2000 in India

Overburden means:
- Un-weathered bed rock – mostly boulders
- Physico- chemical & biological properties not support vegetation
- Acidic (pH <5.2), Nutrient far below from optimum level, No microbes, high bulk density, for low OC & N
- Extensive area – unmanageable land.

= "biologically dead soil"

Global warming/ climate change
Mitigation

C- SEQUESTRATION IN SOILS
(One of Mitigation method)

Soil–C Sequestration by RMPs

Safer World with Food Security

Impact

Soil amendment with Organic manures

Soil–C Sequestration by Degraded lands Restoration (A/R)

Mechanisms
1. Physical occlusion
2. Chemical interactions (clay)
3. Biochemical recalcitrance

Soil Fertility Restoration & High productivity

- High Photosynthesis Rate
- High C to N ratio
- High C: N level & Inclusion of C in Soil improves by RMPs

- High SOC, SN & High avail Nutrient
- High Vegetation & biomass
- High Soil aggregates stability & BD
- High WHC & Soil moisture
- Conserve soil & water
- High S-C Sequestration potential

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Forests and Climate change

Changes in bulk density after 3-months

Fig - 1 Bulk density of coal mine – organic manure treated soils
Before: Freshly vermicomposted soil;
After: 3-month old vermicomposted soil

Fig – 3 Species response on coal mine – organic manure treated soils

(1). Control (Tc)
(2) Mined soil 150kg + Sand (7.5kg) + VC 7.5kg (T1)
(3). Mined soil 150kg + Sand (15kg) + VC 15kg, (T2)
(4). Mined soil 150kg + Sand (22.5kg) + VC 22.5kg (T3)
(5) Mined soil 150kg + Sand (30kg) + VC 30kg (T4)
(6) Mined soil 150kg + Sand (7.5kg) + VL 15 litre (T5)
(7) Mined soil 150kg + Sand (15) + VL 22.5 litre (T6)
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METHODOLOGY

Physico-chemical properties

Experimental Design

Organic manures

Tree species

Promising species

Coal mine soil

At the end of 1st month

At the end of 3rd month

PLATE SHOWING THE GROWTH RESPONSES OF SELECTED SPECIES IN DIFFERENT TREATMENT

Tree response

Table:

<table>
<thead>
<tr>
<th>Tree species</th>
<th>Acacia</th>
<th>Mahogany</th>
<th>Sissoo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>82.2</td>
<td>44.4</td>
<td>61.11</td>
</tr>
<tr>
<td></td>
<td>72.2</td>
<td>98.8</td>
<td>94.4</td>
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<tr>
<td></td>
<td>16.66</td>
<td>17.77</td>
<td>18.8</td>
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<td></td>
<td>66.6</td>
<td>50</td>
<td>34.4</td>
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<td></td>
<td>71</td>
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<td>80</td>
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Biometric data

Promising species

Babul

Mahogany

Shisham

Prosophis

Germination %

Survival %

Fig - 2 Changes in bulk density after 3-months
Before: Freshly vermicomposted soil;
After: 3-month old vermicomposted soil

Fig - 1 Bulk density of coal mine – organic manure treated soils

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1st Indian Forest Congress - 2011

Conclusion

- Babul is most promising tree species for mine lands
- Incorporation of sand in mine soil reduce bulk density, increase porosity & WHC
- But unexpected changes in chemical properties with vermicompost – need through deep research to confirm its behaviour.

Fig – 2. Chemical properties of coal mine – organic manure treated soils
Before: Freshly vermicompost soil,
After: 3-month old vermicompost soil.

Changes in pH, OC & OM after 3-months
A Cost effective strategy for forestry based climate change mitigation in India: CDM program of Activities with TOF.

PP Bhojvaid, IFS and Promode Kant

Forests are both source and sink

- **Source**
  - Deforestation
  - Fire and degradation
  - Around 15% warming is attributed to these

- **Sink**
  - Photosynthesis
  - Biomass assimilation

India’s forests and CC

- Different GC models have been used in IPCC report
- Significant effect on forests
- Both structure and function
- By 2085 70% forest grids are likely to shift
- May affect NPP of Forests
- Forest planning and policies should take account of this
India’s forests and CC:ICFRE report 2009

- 135.15 million tons of CO\text{2}e yr\textsuperscript{-1}
- This can neutralize 9.31 of countries emission at 2000 level
- Even if sequestration remains stagnant at this level
- Forests will offset 6.53% and 4.87% of projected increased emissions

Paradigm Shift: Focused Management

- Payment of environmental Services: Geographic
- Dimension of Growth and Development
  - Variation in Development: VP
  - Smart Payments: JS
- Climate change and Forests: Opportunities and challenges
  - Adaptation and mitigation: drought and productivity
  - Low volume High Value tropical Crops (MP)
  - Smart subsidies for agro/farm forests..sequestration
  - Afforestation and reforestation

Comparative Figures for Forest cover

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>Asia</th>
<th>South and South East Asia</th>
<th>India</th>
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</thead>
<tbody>
<tr>
<td>Forest cover</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>as % of land</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Forest Productivity

<table>
<thead>
<tr>
<th>Country</th>
<th>Global Average</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Haryana

<table>
<thead>
<tr>
<th></th>
<th>Classified</th>
<th>TOF</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (Km\textsuperscript{2})</td>
<td>1517 (1558)*</td>
<td>1415</td>
<td>2932</td>
</tr>
<tr>
<td>% of TGA</td>
<td>3.43</td>
<td>3.20</td>
<td>6.63</td>
</tr>
<tr>
<td>Growing Stock</td>
<td>2.37</td>
<td>15.36</td>
<td>17.33</td>
</tr>
<tr>
<td>million M\textsuperscript{3}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per ha Growing</td>
<td>15.3</td>
<td>108.5</td>
<td>62.5</td>
</tr>
<tr>
<td>Stock M\textsuperscript{3}</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trees per ha CNFA = 12.3  Total Trees = 50 million
Area TOF > 1 ha block = 834 KM\textsuperscript{2}

Haryana Analysis

- Classified Forests
  - Main species, Eucalyptus, Acacias, Dulbergia and Misc.
  - Rotation 15-50 years
  - Average 30 yrs
  - MAI 0.5 M\textsuperscript{3} Yr\textsuperscript{-1}
  - Most planting by seedlings of seed origin
  - Large scope for improvement

Based on SFR 2003.
Forests and Climate change

Haryana TOF
- Most plantations under AF
- QGS poplars and Eucalyptus
- Good fertile soils, Better protection
- Ensured irrigation and fertilization?
  - Rotation 5-10 years
  - Average 7 yrs
  - MAI 15-18 M³ Yr⁻¹
- Still major planting stock from seeds

PUNJAB

<table>
<thead>
<tr>
<th></th>
<th>Classifie d Forests</th>
<th>TOF</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree cover (Km²)</td>
<td>1580</td>
<td>1608</td>
<td>3188</td>
</tr>
<tr>
<td>% of Total Geographical Area</td>
<td>3.14</td>
<td>3.19</td>
<td>6.33</td>
</tr>
<tr>
<td>Growing Stock million M³</td>
<td>11.08</td>
<td>17.90</td>
<td>28.98</td>
</tr>
<tr>
<td>Per ha Growing Stock M³</td>
<td>35.20</td>
<td>110.70</td>
<td>-</td>
</tr>
<tr>
<td>Rotation age of tree species (years)</td>
<td>35</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Mean annual increment M³ ha⁻¹ Year⁻¹</td>
<td>1.1</td>
<td>15.81</td>
<td>-</td>
</tr>
</tbody>
</table>

Haryana TOF
- Most plantations under AF
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- Good fertile soils, Better protection
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UP

<table>
<thead>
<tr>
<th></th>
<th>Classifie d Forests</th>
<th>TOF</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree cover (Km²)</td>
<td>14118</td>
<td>7715</td>
<td>21833</td>
</tr>
<tr>
<td>% of Total Geographical Area</td>
<td>5.86</td>
<td>3.20</td>
<td>9.06</td>
</tr>
<tr>
<td>Growing Stock million M³</td>
<td>164</td>
<td>88</td>
<td>252</td>
</tr>
<tr>
<td>Per ha Growing Stock M³</td>
<td>99</td>
<td>114</td>
<td>-</td>
</tr>
<tr>
<td>Rotation age of tree species (years)</td>
<td>80</td>
<td>27</td>
<td>-</td>
</tr>
<tr>
<td>Mean annual increment M³ ha⁻¹ Year⁻¹</td>
<td>1.2</td>
<td>4.5</td>
<td>-</td>
</tr>
</tbody>
</table>

Block Plantations Eucalyptus

Seedlings:
Genetic variability
Low Yields
The MAI realized under Agroforestry for species such as Poplar and Eucalyptus

- Poplar  
  10 - 25 m³ ha⁻¹ year⁻¹  
  (Haryana and UP)
- Eucalyptus  
  8 - 14 m³ ha⁻¹ year⁻¹  
  (Haryana)
- ITC Clonal Eucalyptus  
  35 m³ ha⁻¹ year⁻¹  
  (AP)
- ITC Clonal Eucalyptus  
  22 m³ ha⁻¹ year⁻¹  
  (Haryana, under trial)

Five-year-old Eucalyptus forest productivity 40 m³ / ha / year

CLONING OF EUCALYPTUS OPERATIONLISED CAPACITY BEING ENHANCED

Enhacement of Eucalyptus Productivity

Seed/clone plantation Vs Clonal
Contemporary Agroforestry in Haryana

- 20 million seedling year\(^{-1}\)
- 20,000 ha year\(^{-1}\)
- Eucalyptus and Poplar
- Quality planting stock
- Private Nurseries

Wood Based Industries

- Research and development
- Establishment of industries
- In state value addition

Agroforests & Industries

- 1.6 million m\(^3\)
- Enabling environment
- Adequate Infrastructure

Other Environmental Benefits

- CO\(_2\) sequestration
- Increase in tree cover (8%)
- Alleviation of pressure from Natural Forests: hence a case for REDD+
- Biodiversity conservation

Wood Based Industries

- 600 plywood units
- Purchase 1 million US$ day\(^{-1}\)
- Value added 3 million US$ day\(^{-1}\)
- 60,000 man days day\(^{-1}\)
- 2.5 million $US as tax month\(^{-1}\)

Poplar with Asparagus recemosa
Lessons learnt from Haryana

- Changes in rainfall pattern
- Late arrival of Monsoon
- Number of rainy days
- Results into too much and too less
- Mortality of new saplings
- Loss of time and money
- Wasted efforts

Lessons continued

Out of Box thinking

Change in patterns
1. Earth work
2. Planting time

Base line scenario: the usual landscape
Improvisation in interventions

Optimization of landuse

Plantations created in April put on incremental growth

Higher success

Five year old plantation

Adaptation of model by farmers

Other crop same model
Factors contributing to the success story

- Role of FD
- Infrastructure
- Innovations
- Technology
- Legal policy regime
- People
- Private sector

Common landscape: TOF

Low volume high value crops

Innovative models

Way Ahead

- Forest policy: 33% tree cover & Increased productivity
- State Forests: difficult
  - degraded
  - Cost per tree 80-100 INR
  - MAI 2-4 m³
- Agroforestry: good fertile lands
  - Cost per tree: 10-20 INR
  - MAI 12-40 m³

Cost per tree: 80-100 INR
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MAI 12-40 m³

Low volume high value crops

Common landscape: TOF

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Cost per tree: 80-100 INR
- MAI 2-4 m³

MAI 12-40 m³
The projected concentration of CO2 in the year 2100 ranges from 540 to 970 ppm, compared to about 280 ppm in the pre-industrial era and about 368 ppm in the year 2000.

Increase in globally averaged surface temperature of 1.4 to 5.8°C over the period 1990 to 2100.

Increases of both atmospheric CO2 and temperature are expected to affect ecosystem structure and functions.

Dr. N. Senthilkumar
Division of Bioprospecting
Institute of Forest Genetics and Tree Breeding
(Indian Council of Forestry Research & Education)
Coimbatore, Tamilnadu
The world geographical area = 14894 m ha
India's geographical area = 328.7 m ha
World forest area = 3952 m ha
India's forest area = 67.7 m ha
(Between 1990 and 2005, India gained 3,762,000 hectares (5.9%) of its forest cover.)

35% of world's existing terrestrial habitat predicted to be altered

Studies found that deforestation in different areas of the globe affects rainfall patterns over a considerable region.

Per capita carbon emission, by income classes (kg C/year)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
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<tbody>
<tr>
<td>Top class &gt;5 lakhs /yr</td>
<td>873.6</td>
<td>894.15</td>
<td>898.26</td>
<td>914.7</td>
<td>935.25</td>
<td>955.8</td>
</tr>
<tr>
<td>Middle class 50,000-5 Lakhs</td>
<td>245.7</td>
<td>262.55</td>
<td>265.92</td>
<td>279.4</td>
<td>296.25</td>
<td>313.1</td>
</tr>
<tr>
<td>Bottom class &lt;50,000</td>
<td>103.4</td>
<td>112.95</td>
<td>114.86</td>
<td>122.5</td>
<td>132.05</td>
<td>141.6</td>
</tr>
<tr>
<td>All India</td>
<td>127.9</td>
<td>200.5</td>
<td>215.08</td>
<td>273.2</td>
<td>345.85</td>
<td>418.5</td>
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(Inc. per capita per year: Top =2.055 kg C/year, Middle = 1.685 kg C/year, Bottom = 0.955 kg C/year, All India = 7.265 kg C/year.)

Archana Warran & Ankur Patwardhan, 2003

How forest sector is relevant to Climate Change?

- As a source (deforestation and forest degradation)
- Impacted by the Climate Change
- As a sink (Existing natural forests)
- Offer opportunities for C-sequestration (Afforestation, reforestation & existing plantations)

CLIMATE CHANGE

- One of the most important global environmental challenges.
- Impacts needed to be understood & assessed.
- Vulnerability needed to be addressed
- Adaptation needed to be initiated

The world geographical area = 14894 m ha
India's geographical area = 328.7 m ha
World forest area = 3952 m ha
India’s forest area = 67.7 m ha
(Between 1990 and 2005, India gained 3,762,000 hectares (5.9%) of its forest cover.)

Per capita carbon emission, by income classes (kg C/year)

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<tr>
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<td>141.6</td>
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<tr>
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(Inc. per capita per year: Top =2.055 kg C/year, Middle = 1.685 kg C/year, Bottom = 0.955 kg C/year, All India = 7.265 kg C/year.)

Archana Warran & Ankur Patwardhan, 2003

How forest sector is relevant to Climate Change?

- As a source (deforestation and forest degradation)
- Impacted by the Climate Change
- As a sink (Existing natural forests)
- Offer opportunities for C-sequestration (Afforestation, reforestation & existing plantations)

CLIMATE CHANGE

- One of the most important global environmental challenges.
- Impacts needed to be understood & assessed.
- Vulnerability needed to be addressed
- Adaptation needed to be initiated

The world geographical area = 14894 m ha
India's geographical area = 328.7 m ha
World forest area = 3952 m ha
India’s forest area = 67.7 m ha
(Between 1990 and 2005, India gained 3,762,000 hectares (5.9%) of its forest cover.)

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Forests and Climate change

The forest area - carbon stock = 63.86 Mha
wood (stem) biomass = 4327.99 Mt
growing stock (GS) = 2398.19 Mt
carbon stock = 1085.06 Mr of Indian forests

Of which, the Conifer stocked maximum carbon in their woods,
Conifer forest: 28.88 to 65.21 t ha-1
Mangrove forests: 20-24 t C ha-1
Dipterocarp forests: 9.01 t C ha-1
Shorea robusta forests: 23.07 t C ha-1
Butea frondosa, 3.91 t C ha-1
(with 0.22 Mha forest area)

1983-1984
The biomass density/ha in Indian forests is 67 t/ha.
Carbon stock in Indian forests = 2033 million tonnes.

Carbon stock in forests

<table>
<thead>
<tr>
<th>Year</th>
<th>Managed Forest</th>
<th>Reserve Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>170.54</td>
<td>223.81</td>
</tr>
<tr>
<td>1994</td>
<td>163.79</td>
<td>232.66</td>
</tr>
</tbody>
</table>

Median carbon storage by agroforestry practices

- 9 tC/ha in semi-arid
- 21 tC/ha in sub-humid
- 63 tC/ha in temperate ecozones.

Biomass and carbon stock

<table>
<thead>
<tr>
<th>Plantation model</th>
<th>Above ground biomass (t/ha)</th>
<th>Rate of accumulation of biomass (t/ha)</th>
<th>Above ground carbon stock (t/ha)</th>
<th>Rate of accumulation of carbon stock (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poplar</td>
<td>55</td>
<td>2.13</td>
<td>851</td>
<td>1251</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>43</td>
<td>1.64</td>
<td>963</td>
<td>1473</td>
</tr>
<tr>
<td>Teak</td>
<td>74</td>
<td>2.85</td>
<td>1944</td>
<td>2914</td>
</tr>
<tr>
<td>Mango</td>
<td>38</td>
<td>1.46</td>
<td>857</td>
<td>1285</td>
</tr>
<tr>
<td>Lichi</td>
<td>38</td>
<td>1.46</td>
<td>857</td>
<td>1285</td>
</tr>
<tr>
<td>Poplar bund plantation</td>
<td>37</td>
<td>1.42</td>
<td>834</td>
<td>1251</td>
</tr>
<tr>
<td>Eucalyptus bund plantation</td>
<td>42</td>
<td>1.62</td>
<td>951</td>
<td>1428</td>
</tr>
</tbody>
</table>

@ carbon price of US$4/tCO₂

Ravindranath, 2008

Koul and Pawar, 2008

Above-ground mean tree biomass density

- Reserved forest = 1158 t ha-1
- Protected forest = 728
- Fallow land = 13
- Cultivated-unirrigated land = 11
- Grassland = 8
- Orchard land = 5
- Cultivated-irrigated land = 3 t ha-1.

Koul and Pawar, 2008
Major insect pests that affect trees in India

- **Defoliator** - Calopepla leayana (Chrysomelidae) Gmelina arborea
- **Bud shoot feeder** - Dioryctria sp. (Pyralidae) Pinus sp.
- **Defoliator** - Hybleaea puera (Hyblaeidae) Teak
- **Defoliator** - Eutectona machaeralis (Pyralidae) Teak
- **Wood borer** - Hoplocerambyx spinicornis (Cerambycidae) Shorea robusta
- **Bud shoot feeder** - Hypsipyla robusta (Pyralidae) Mahogany
- **Sap feeder** - Tingis boesi (Tingidae) Gmelina arborea
- **Wood borer** - Xyletus ceramica (Cerambycidae) Teak, Gmelina
- **Wood borer** - Xystoscerus festiva (Cerambycidae) Paraserianthes falcataria
- **Gall inducer** - Leptocybe invasa (Eulophidae) Eucalyptus
- **Subterranean** - Termites (Termitidae) Eucalyptus
- **Bark eating caterpillar** - Indarbela quadrimaculata on Casuarina equisetifolia

Forest biomass loss due to insects disturbance 1m ha/yr

<table>
<thead>
<tr>
<th>Area under disturbance</th>
<th>Tropical</th>
<th>Temperate</th>
<th>Subtropical</th>
<th>Alpine</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insect</td>
<td>14341</td>
<td>656</td>
<td>1260</td>
<td>519</td>
<td>16776</td>
</tr>
<tr>
<td>Annual loss</td>
<td>-1.6</td>
<td>-0.2</td>
<td>-0.2</td>
<td>-0.1</td>
<td>-2</td>
</tr>
<tr>
<td>Dead biomass</td>
<td>-382</td>
<td>-32</td>
<td>-32</td>
<td>-15</td>
<td>-416</td>
</tr>
</tbody>
</table>

Haripriya, 2001

Forest damage

Pest outbreaks as major source of natural disturbance.

The effects vary from defoliation and growth loss, to timber damage, to massive mortality.

North America- 2.9% p.a.

Insect damage – world scenario

In 1994-2002, US- 5 m ha – 1.7%
Canada – 14 m ha – 4.5%

India ?

Insect pests spectrum in a tree

Areas under Forest loss - Annually by

- Diseases: 8,469,000 ha
- Fire: 3,700,000 ha
- Insects: 1,000,000 ha

Forest biomass loss due to insects disturbance 1m ha/yr

- Carbon in biomass and mean annual increment (t C/ha)
- Insect damage – world scenario
- In 1994-2002, US- 5 m ha – 1.7%
- Canada – 14 m ha – 4.5%
- India ?
Forests and Climate change

Unprotected area = 31% biomass loss = wood volume = 184.3 m³
Protected area = 4% biomass loss due to insect attack = 170 m³ (1250 trees each)
Each tree volume in protected area = 0.14791 m³
Unprotected area = 0.1360 m³

KFRI, 2003
Determine the total (green) weight of the tree
The algorithm to calculate the weight of a tree is
\[ W = \frac{0.15D^2H}{10} \]
where:
- \( W \) is the weight of the tree in pounds
- \( D \) is Diameter of the trunk in inches
- \( H \) is Height of the tree in feet

For trees with \( D < 11 \):
- The atomic weight of Carbon is 12.0011
- The atomic weight of Oxygen is 15.9994
- The ratio of CO2 to C is \( \frac{43.999915}{12.001115} = 3.6663 \)

For trees with \( D \geq 11 \):
- The atomic weight of Carbon is 12.0011
- The atomic weight of Oxygen is 15.9994
- The ratio of CO2 to C is \( \frac{43.999915}{12.001115} = 3.6663 \)

The total green weight of the tree, multiply the above-ground weight of the tree by 120%.

Determine the dry weight of the tree
The weight of carbon dioxide sequestered in the tree per year
Divide the weight of carbon dioxide sequestered in the tree by the age of the tree.

Determine the dry weight of the tree
Therefore, to determine the dry weight of the tree, multiply the weight of the tree by 72.5%.

Determine the percentage of dry matter and moisture in the tree
The average tree is 72.5% dry matter and 27.5% moisture.

Determine the carbon content of the tree
The average carbon content is generally 50% of the tree’s total volume. Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120%.

Determine the total (green) weight of the tree
Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

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Forests and Climate change

Why Pest Management?

- Insects are major, but frequently overlooked ecosystem components that influence their structure and functions
- They are generally neglected in global change research

Carbon Sequestration by US Forests

- U.S. forests sequester carbon at a rate of 250 MMTC/yr — 15% of U.S. emissions
- At $5/ton, annual value of sequestration is more than $1 billion
- It is technically feasible to increase the rate of carbon sequestration in forests by 150 MMTC/yr:
  - Afforestation
  - Improved management
  - Efficient wood production
  - Bio-products and energy
  - Agroforestry

Carbon stocks in India's forest tree cover (million tonnes)

- Stand biomass of *Gmelina arborea* ranged from 3.94 (1-year-old) to 53.67 t ha$^{-1}$ (6-year-old) and stand carbon in 6-year-old plantations ranged from 24.12 to 31.12 t ha$^{-1}$. At 6 years, *G. arborea* stands sequestered 31.37 t ha$^{-1}$ carbon

Climate change & insects

- Insect herbivory of plants in high CO$_2$ environments is dramatically increased.
- Management of natural forests as CO$_2$ sinks will need to be adjusted to compensate for this increase in defoliation.
- If insects and other forest pests adapt a more aggressive consumption pattern in a future global climate, net CO$_2$ sequestration of future forests may be less than it is in current condition.
Plant trees – Let's all be a little bit greener

Of the total accessible biomass, only 0.31% was extracted annually by the local people for fuel, fodder and other uses. Forest biomass production was simulated for the next 30 years with a logistic growth model. The model results highlighted the declining forest resources in the long run.

appropriated
Government policies
Management plan
Afforestation
Tree cultivation in private lands
Agroforestry can, however, increase the rate of carbon sequestration.
Forests and Climate change

The concentration of CO₂ and other greenhouse gases (GHGs) in the atmosphere has considerably increased over the last century and is set to rise further. Increasing levels of atmospheric CO₂ will stimulate photosynthesis and productivity in most ecosystems; the duration and magnitude of this stimulation is especially in medicinal plants not yet studied. Adjustments at the physiological, organism, and ecosystem levels have the potential to moderate the growth response to elevated CO₂. Under climatic change conditions their structure and function may greatly change, their integrity may be violated and their services to people may be greatly modified. World trade mainly based on the presence of quality and quantity of active principles. Exporters, traders and mainly farmers struggling to market their products in the world trade due to changes in the active ingredients. The present study is proposed to understand the response of the medicinal plants to the elevated CO₂ levels under simulated temperature and moisture regimes.

Purpose of the study

- 2nd largest producer of medicinal plants.
- Share in global trade is about 2.5% (China 13%).
- Domestic trade of 80-90 billion (Export 10 billion).
- World trade expected to reach US $ 7 trillion by 2050.
- Medicinal plants are mainly the alternate income-generating source of underprivileged communities.
- Steady increase for demand, overexploitation.
- Farmers showing interests in cultivation under farmland conditions.
- World trade mainly based on the presence of quality and quantity of active principles.

Elevated CO₂ effect on Photosynthetic behavior and Bio-chemical changes in Ocimum sanctum Linn. an Medicinal herb

S. Saravanan, Karthik, L and R.S.C. Jayaraj

Forestry Land Use and Climate Change division
Institute of Forest Genetics and Tree Breeding
Forest Campus, PB.NO: 1061, R.S. Puram, Coimbatore - 641 002
Highest protein registered under control and least in ambient.

Under 600 ppm, the total phenols content recorded higher and least in 900 ppm.

Under 900 ppm, the Carbohydrates registered higher and lowest in ambient condition.
Conclusions

1. Effect of elevated CO$_2$ on growth, physiological and bio-chemical changes was observed in Ocimum.

2. Best growth was observed under the 600 ppm+RH control chamber and least under ambient condition.

3. The same trend was observed in chlorophyll ‘a’, ‘b’ and total and other parameters like root:shoot ratio, no. of leaves, primary and secondary roots, etc.

4. Higher germination was registered under the 600 ppm+RH and least under 900 ppm.

5. Photosynthetic parameters showed higher under the 600 ppm+RH and least under ambient condition.

6. Bio-chemical analysis shows different results. Highest phenols under 600 ppm, Protein under control and Carbohydrates, Flavonoids and Tannin registered highest under the 900 ppm.

Tannin and Flavonoids registered higher under 900 ppm and lowest in ambient condition.