SAARC

भारतीय वन सर्वेक्षण
Forest Survey of India

South Asian Association for Regional Cooperation

SAARC Training Workshop on Measurement and Estimation of Forest Carbon Stock

Organized by the SAARC Forestry Centre
In Collaboration with Forest Survey of India, Dehradun
Date: 22 - 26 November, 2010

Manual

In Commemoration of 25 Years of SAARC

MEASUREMENT AND ESTIMATION OF FOREST CARBON STOCK

SAARC Training Workshop on Measurement and Estimation of Forest Carbon Stock

November 22 -26, 2010

Table of Contents

Abbreviation	Full Form
AFOLU	Agriculture, Forestry and Other Land Use
AWG-LCA	Ad Hoc Working Group on Long-term Cooperative Action under the Convention (UNFCCC)
BCEF	Biomass Conversion and Expansion Factor
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
COP	Conference of Parties
DGPS	Differential GPS
DOM	Dead Organic Matter
EHZ	Eastern Himalayan physiographic Zone
FAO	Food and Agriculture Organization
FRA	Forests Resource Assessment
FRI	Forest Research Institute
FSI	Forest Survey of India
GHG	Green House Gases
GLONASS	GLObal Navigation Satellite System
GPG	Good Practice Guidance (IPCC)
GPS	Global Positioning System
ICFRE	Indian Council of Forestry Research and Education
IGNFA	Indira Gandhi National Forest Academy
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change & Forestry
MMU	Minimum Mapping Unit
NASA	National Aeronautics and Space Administration
NFDMS	National Forest Data Management System
NFI	National Forest Inventory
NRSA	National Remote Sensing Agency
PCCF	Principle Chief Conservator of Forest
PRC	Pseudo Random Code
REDD	Reducing Emissions from Deforestation and Degradation
SAARC	South Asian Association for Regional Cooperation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SFM	Sustainable Fores Management
SOC	Soil Organic Carbon
TAR	Third Assesment Report
TFI	Training and Forest Inventory
TOF	Trees Outside Forest
UNFCCC	United Nations Framework Convention on Climate Change
VEF	Volume Expansion Factor
CCX (VER)	Chicago Climate Change (Voluntary Emission Reduction)
WII	Wildlife Institute of India

List of Trainers/Resource Persons and Participants

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SAARC TRAINING WORKSHOP
ON MEASUREMENT AND ESTIMATION OF FOREST CARBON STOCK
Conducted by SAARC Forestry Centre
in Collaboration With
Forest Survey of India, Ministry of Environment and Forests,
Government of India.
Venue :Forest Survey of India, Dehra Dun
Date :22 – 26 November 2010.

Participants being taught to lay out sample plots, measure tree diameter and height, collection of soil sample, measuring regeneration, weighing over ground biomass (grasses and twigs).

Welcome Address

Mr. Ranjit Singh Gill, Joint Director (TFI)
Forest Survey of India

Honorable Dr.J.K. Rawat, Former Director General, Forest Survey of India and former PCCF, Haryana, Dr.Jagdish Kishwan, Additional Director General (Wildlife), Government of India, Dr. Sangay Wangchuk, Director, SAARC Forestry Centre, Thimpu, Bhutan, Mr. Pasang W. Norbu, Sustainable Forests Management Specialist, SAARC Forestry Centre, Thimpu, Bhutan, Dr. R.D. Jakati, Director General, Forest Survey of India, delegates from SAARC Member Countries participating in the SAARC Training Workshop, distinguished guests, ladies and gentlemen.

It gives me great pleasure to welcome this august gathering to the inauguration of the SAARC Training Workshop on 'Measurement and Estimation of Forest Carbon Stock'. Carbon stocks on earth have become the key to our lives, because these stocks tell us the net balance of greenhouse gases in the atmosphere. The entire world is focused on the condition of our environment and the global warming that will inevitably result from the uncontrolled discharge of greenhouse gases into the atmosphere. While the discharge of these gases may happen from several sources, deforestation and destruction of forests is a key cause. More significant than the emission of carbon due to man-made activities and disturbances in the forests is the positive impact the forests play in the sequestration of carbon. Carbon is held not merely in the lush branches and trunks of the trees we see in front of us but also in the components of trees below the ground, in the dead wood and litter and – a crucial factor that is often completely overlooked – in the soil. Together, these pools of carbon are the very pools of our lives.

This conference is about the estimation and measurement of forest carbon pools. We will attempt to understand the dynamics that lie behind the storage of carbon in these pools, the intricacies of the emission of carbon by sources and its removal by sinks in managed land and the measurement of these stocks. The five days of this workshop shall combine theory sessions with a practical experience in the field. Carbon measurement is a key concern for all countries. We would be grateful to the participants from SAARC countries to explain the measures being adopted in their respective countries. The sharing of experience shall be to the mutual benefit of everyone.

This workshop must begin a process of regular interaction and exchange between SAARC countries to strengthen their shared knowledge and cooperation. We live in a single part of the world, our challenges and opportunities are similar and there should be a similarity in the way we address these challenges. I am thankful to the SAARC Forestry Centre, Thimpu, Bhutan for getting us all together here for this workshop.

Ladies and gentlemen, I warmly welcome you to India, to Dehradun, to FSI and to this shared endeavour. I hope each one of you will benefit from this workshop. I trust this workshop will lead to many similar exchanges of ideas in the future.

Thank you.

Mandate of SAARC Forestry Centre (SFC)

Dr. Sangay Wangchuk
Director

History

During the Third SAARC Summit (Kathmandu, 1987), leaders of the SAARC Member States were deeply concerned by the fast and continuous degradation of the environment including extensive destruction of the forests and the resulting natural disasters. Subsequently the leaders commissioned a study on the Protection and Preservation of the Environment and the Causes and Consequences of Natural Disasters. The recommendations of the Expert Group who finalised the format of the Study were endorsed by the Heads of State or Government at the Sixth Summit (Colombo 1991).

The Fourth SAARC Summit (Islamabad, 1988) noted with serious concerns the extensive damage caused in many SAARC Countries during the year due to unprecedented floods, cyclones and earthquakes. The leaders recalled their earlier decision to enhance regional cooperation with the view to strengthening disaster management capabilities. They then urged that a Study on Greenhouse Effect and its impact on the Region should be completed urgently which would then provide a basis for an action plan for meaningful cooperation among the Member States.

The Fifth SAARC Summit (Male, 1988) was satisfied with the methodology recommended for the Study on the Greenhouse Effect and it Impacts on the Region. The study was finalized in 1992. The Study had the following components:

1. Regional measures in sharing experiences, scientific capabilities and information on climate change; and
2. Global collaboration in Monitoring Climatology, Sea Level Rise, Natural Disasters, Technology Transfer, Finance etc.
3.

The Seventh SAARC Summit (Dhaka, 1993) recognized the completion of the Study as a very significant step towards promoting regional cooperation in this vital area.

The Third Meeting of the Environmental Ministers (Male, 1997) adopted the SAARC Plan of Action on Environment based on the two studies outlined above.

The Fourth Meeting of Environment Ministers (Colombo, 1998) recalled various major international instruments and declarations on environment and noted the importance of enhanced cooperation in sharing information in the region to promote effective management of the environment for the benefit of all the member States.

However, no common institution in the area of forestry and environment was established for the SAARC countries to deal with common issues related to forest and environment.

The SAARC Action Plan on Environment provided basis for the establishment of the SAARC Forestry Centre in Bhutan as one of the Centres of Excellence in the field of forestry and environment.

Therefore, at the Sixth SAARC Ministerial Meeting on Environment (Thimphu, June 2004), the Technical Committee on Environment and Forestry recommended for establishment of SAARC Forestry Centre in Bhutan.

An Expert Group was then formed to formulate aims and objectives of the Centre, suggest an operating modalities and collaborative networking & linkages among the national forestry and environmental institutions of the SAARC Member States.

The Twenty-fifth Session of the Council of Ministers (Islamabad, July 2004) approved the establishment of the SFC in Bhutan.

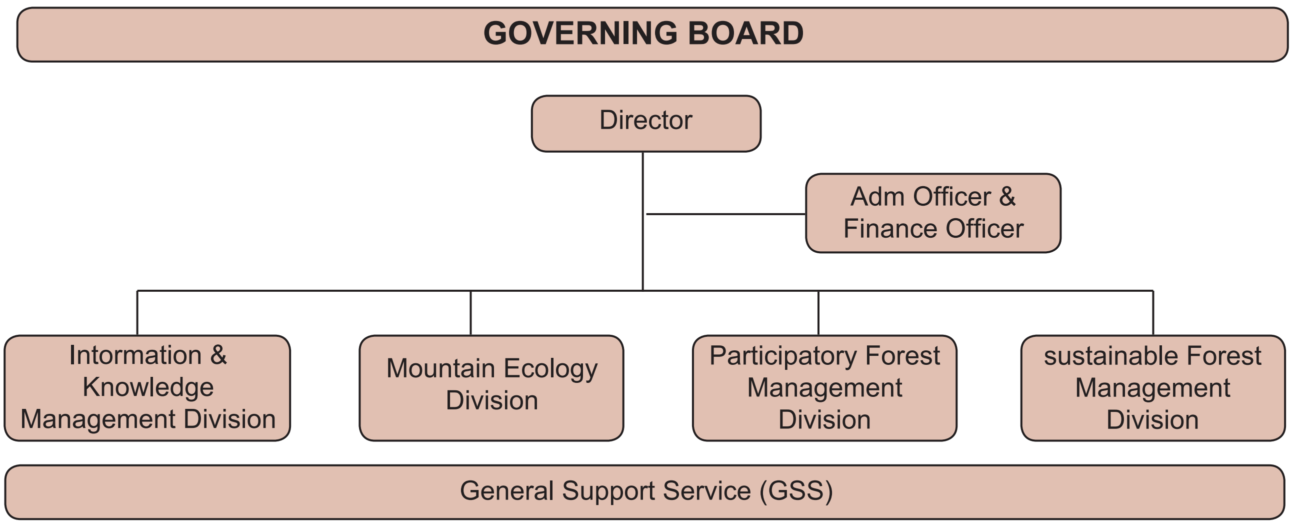
The Thirteenth SAARC Summit (Dhaka, 2005), welcomed the decision of the Council of Ministers to establish the SAARC Forestry Centre in Bhutan.

Subsequently, a Governing Board for the SAARC Forestry Centre was established in November 2007 and on 11th June 2008, SAARC Forestry Centre Office in Bhutan was officially inaugurated jointly by His Excellency, Dr. Sheel Kant Sharma, SAARC Secretary General and Dr. Pema Gyamtsho, the Honorable Minister, Ministry of Agriculture, Royal Government of Bhutan.

Mission

Protection, conservation and prudent use of forest resources by adopting sustainable forest management paradigm through research, education and coordination among the SAARC member countries to contribute towards sustainable development and conservation of global environment.

Organogram



Procedures to Recruit Staffs for Regional Centres:

1. Director
    - Nominated by the Host Government
2. Professional Staffs
    - Recruited through Regional Competition/Interview of candidates from the Member States
3. General Support Staffs
    - Only Nationals of the host country are recruited through interview as per the Harmonized Provisions Relating to the Financial and Administrative Matters of the SAARC Regional Centres.

Current Staff Strength:

1. Director - 1
2. Professional Staffs
    - 3 Professional Staffs (already with the Centre)
    - 1 national professional (yet to join the Centre)
3. General Support Staffs
    - 6 General Support Staff

Funding of the Centre's activities:

1. Capital Cost - 100% borne by Host Government
2. Institutional Cost – 40% borne by Host Government and 60% through MS contribution
3. Programme Cost/Budget – 100% is through the Membership Contribution on sliding scale.

Thank You for Your Attention and TASHI DELEK

Over View of Forest Survey of India

Dr. R. D Jakati
Director General, FSI
Dehradun

The Chief Guest of the inaugural function, Dr.J.K. Rawat, Former Director, Forest Survey of India and former PCCF, Haryana, Dr.Jagdish Kishwan, Additional Director General (Wildlife), Government of India, Dr. Sangay Wangchuk, Director, SAARC Forestry Centre, Thimpu, Bhutan, Mr. Pasang W. Norbu, Sustainable Forests Management Specialist,SAARC Forestry Centre, Thimpu, Bhutan, delegates from SAARC countries of Bhutan, Bangladesh, Nepal, Sri Lanka and India who have come all the way from their respective places to attend this Training Workshop, distinguish guest from sister organization, ICFRE, FRI, WII, IGNFA, my colleagues from Forest Survey of India, ladies and gentlemen, It gives me immense pleasures to welcome you all at Forest Survey of India, Dehradun. Lying in the north of India and cradled in the awesome beauty and calm serenity of the Himalayas, Dehradun is the capital of Uttarakhand state and the hub of forestry activities in India.

The Forest Survey of India is an organization under the Ministry of Environment & Forests, Government of India. Its principal mandate is to conduct survey and assessment of forest resources in the country and present its report in the form of State of Forest Report biennially. The headquarters of FSI is located at Dehradun and it has four regional offices located at Shimla (North Zone), Kolkata (East Zone), Nagpur (Central Zone) and Bangalore (South Zone). FSI was created in June, 1981 as a successor to “Pre-Investment Survey of Forest Resources (PISFR)”, a project initiated in 1965 by the Government of India and sponsored by FAO and UNDP, for survey and inventory of forest resources in different parts of the country. The activities of FSI were reviewed in 1986 and its objectives were redefined to make it more purposeful to the needs of the country.

The principal objectives of Forest Survey of India are to prepare a comprehensive State of Forest Report (SFR) including Digital Forest Cover Maps biennially, providing assessment of latest forest cover in the country and monitoring changes in these; conduct inventory of forest and non-forest areas and develop database on forest resources; design methodologies relating to forest surveys and impart training to officers and staff of State Forest Departments in the application of Remote Sensing, GIS and GPS in forestry.

Use of the modern methods and technology has been the prime concern of this organization since its inception in the late 60’s. In the early days of Pre-Investment Survey (PIS), electronic data processing was done with the help of two IBM 1620 computer using IBM punch card and large random access disks. Photo-interpretation using aerial photographs coupled with electronic data processing was the hallmark of forest inventory during the PIS days. Over the years, FSI has expanded its activities manifold and has also upgraded its technology with the changing times. Remote Sensing, GIS and GPS have become extremely important tools in the regular activities of FSI as well as for the various special studies and projects conducted by FSI.

The technological improvement in the quality of data as well as the imaging software had led to improvement in the accuracy of the assessment of the forest cover. With the change in the scale of interpretation from 1:1 million in 1987 to 1:50,000 currently, the minimum mappable area of the assessment has improved from 400 ha in 1987 to 1 ha currently. Remote sensing along with field inventory is also being used by FSI to assess the tree cover of the country. Consequently, FSI is in a position to give a complete picture of the forest and tree cover of the country since 2001.

The other important mandate of FSI is to undertake inventory of forest and Trees Outside Forests in selected districts spread across the country. FSI has been conducting field inventory for estimating the growing stock (volume) and other parameters of the forests by laying out systematic sample plots. So far about 80% of the country's forest areas have been inventoried including some areas more than once and over 135 reports have been published. Since 2002, the national level estimates of growing stock both in forest and outside forest are being generated regularly on a two year cycle. During the forest inventory, the data on herbs, shrubs, climber, deadwood, litter and soil from forest floor are also being collected. The data on these parameters is required for estimation of carbon.

Working Plan which is the backbone of forest management in any division is increasingly being prepared with the help of GIS today. FSI is playing a leading role in helping State Forest Departments in preparation of working plans using GIS by training forestry personnel from various State Forest Departments in the application of Remote Sensing, GIS and GPS.

FSI has also done the work of estimation of carbon stock in India's forest as per the UNFCCC guidelines. I am sure all the delegates will be benefitted from the experience of India in estimation of carbon stock in forest.

I am very thankful to Dr. J.K. Rawat, who was kind enough to accept our invitation to be the chief guest for the inaugural session. In fact, the National forest Inventory was started during Dr. Rawat's time and his contribution in implementing NFI is highly appreciated. I am also thankful to Dr. Jagdish Kishwan, Additional Director General, Govt of India who has accepted our invitation at a very short notice and graced the occasion as guest of honour. Dr. Kishwan has done a lot of work in climate change and contributed a lot in climate change negotiation particularly in REDD and REDD+.

My thanks are also due to Dr. Sangay Wangchuk, Director, SAARC Forestry Centre and Mr. Pasang Norbu, SFM Specialist SAARC Forest Centre who really took a lot of pain to make this workshop happen and gave their full support and co-operation to FSI in organizing the workshop.

I once again welcome all of you and wish all the participants a happy and comfortable stay. I hope the next five days will be fruitful for all the participants and the objective of the training workshop will be accomplished.

Keynote Address by the Chief Guest

Dr. J.K Rawat
Former Director General, Forest Survey of India and
former PCCF, Haryana,

Dr R.D Jakati, Director General Forest Survey of India, Dr Jagdish Kishwan, Additional Director General Ministry of Environment and Forests, Government of India, Dr Sangay Wangchuk, Director, SAARC Forestry Centre, Mr Pasang W. Norbu, Sustainable Forests Management Specialist, SAARC Forestry Centre, participants of this training workshop, ladies and gentlemen A very good morning to all of you.

First of all let me welcome on my behalf all the participants of this workshop, especially those who have come from abroad. I heartily welcome them to India, to the State of Uttarakhand, and to the city of Dehradun. This state is known as the abode of God since a number of holy shrines are situated in its Himalayan Mountains. The city of Dehradun is unique in the sense that it is flanked on its sides by two of the holiest rivers of India, namely river Ganges on the east and river Yamuna on the west. This place where we are sitting lies on the water-parting line, i.e., all the waters or small streams on the east drain into river Ganges and those on the west drain into river Yamuna. If you see the topographical map of Dehradun, you can easily note the geographical significance of this location.

Again, Dehradun is also known as the forestry capital of India, having a number of National level Forestry Institutions. I hope during the next week or so, besides getting to know the facilities provided by Forest Survey of India, you also get an opportunity to visit Forest Research Institute and Wildlife Institute of India. I understand a day in your itinerary has been kept aside for field visit and I hope you get a glimpse of rural and forestry landscape in this part of the country.

Now about this training workshop, let me say that global warming and climate change has been the most important global issue for the last decade or so. All nations are committed to control and reduce net emissions of green house gases measured in quantities of Carbon. Locking of atmospheric carbon in the trees growing in or outside the forests is the best way to accomplish this. But we also have to know that our efforts are really making an impact on the carbon stock in forest areas. Therefore, we need to measure and assess the forest carbon stock periodically. Recently, our Hon'ble Union Minister of Environment and Forests also suggested that those countries contributing more than 1% to the global pool of net emissions of green-house-gases should make such measurements every two years; and those contributing less than 1% should do it every three to four years.

Thus, it is imperative that all countries have a basic scientific and technological infrastructure and adequately trained manpower to carry out this task. In this context, we can realise the importance and significance of this training workshop. I understand that during the workshop, there will be presentations and discussions on assessment of forest cover, estimation of forest growing stock and biomass, measurement of soil carbon, carbon trading, forest inventory methods, etc. These are all important topics and I congratulate SAARC Forestry Centre and Forest Survey of India for organizing a training workshop on such an important subject.

I hope during the workshop, there is also discussion on measurement and assessment of carbon stock in the trees outside forests and estimation of carbon locked in finished wood products. Carbon stock in the finished wood products is generally not taken into account while computing emissions from the forests. All biomass harvested from the forest is treated to have been converted into emission during the same year. In reality, it is not so since all wood harvested is not used as firewood. About 25-40 percent is used as timber in buildings, furniture, panel products, etc. Carbon remains locked in these products for a number of years and in durable timber such as teak, sal, rosewood, mahagony, etc. for more than a century. With better wood preservation techniques, life of wood products can be significantly increased, thus enhancing the carbon stock.

In addition, while employing the techniques and methodology we presently have, we also have to continuously carry out research to upgrade our methodology and database so as to improve accuracy of carbon stock assessment.

I hope this training workshop will make you better equipped to carry out measurement of carbon stock in your forests on regular basis and enable your government to fulfill its national commitment. I am pleased to inaugurate the training workshop on measurement and estimation of forest carbon stock and pray for its success.

Thanks.

Vote of Thanks

Mr. M.L Srivastava
Joint Director (NFDMS), FSI.

On the behalf of the Forest Survey of India I extend my sincere thanks to the H'ble chief guest Dr. J.K.Rawat; Addl. DG, Government of India, Dr. Jagdish Kishwan, the Director General, Forest Survey of India, Dr. R.D.Jakati, Director, SAARC Forestry Centre, Bhutan, Dr. Sangay Wangchuk, Mr. A.K.Lal, Mr. Passang W. Norbu, participants from the SAARC Forestry Centre, Bhutan. Thanks are due to the participants from the SAARC countries Bhutan, India, Nepal, Sri Lanka, Bangladesh who could finally arrive and add to the sheen of the event.

Thanks are also due to the participants from the states, esteemed guests from various parts of India and to the institutions IGNFA, ICFRE, WII, CASFOS, IIRS, State Forest Department of the Government of Uttarakhand, State Forest departments of other participant states. Special thanks are due to the SAARC Secretariat, Kathmandu for taking the initiative and also for providing the resources for the successful holding of the event. Thanks are due to the Ministry of Environment & Forests, Government of India, Ministry of Foreign affairs, Ministry of Home affairs for extending the necessary permissions. The officers and staff of the Forest Survey of India deserve profound thanks for their untiring efforts for the success of the event. Thanks are also due to all the support staff of FSI. Thanks are also due to the print and visual media for covering the event. On the behalf of the Forest Survey of India, I thank one and all including those whose names may have not been taken inadvertently for participating in this international workshop towards its success.

As pointed out by H'ble chief guest and the Director General Forest survey of India, scientific studies regarding carbon and its different variants are passionately being pursued the world over. In earlier days we talked about the Carbon dating, carbon copy etc. Now a paradigm shift is there to carbon efficiency, low carbon economy, carbon credits, carbon offsets to carbon footprint as it is integrally associated with our very existence. Carbon is essentially an integral part of discussions in academia and civil society.

In the backdrop of REDD and REDD$^+$ under UNFCCC which are major drivers for conservation. REDD$^+$ includes conservation, sustainability and enhancement of carbon stock. Thus scientifically verifiable, universally acceptable carbon stock estimation mechanism is a must. The current workshop strives to address this issue and will hopefully be a valuable input for all the participants.

Once again on the behalf of the Forest Survey of India, I thank one and all associated with this event.

Technical Session 1

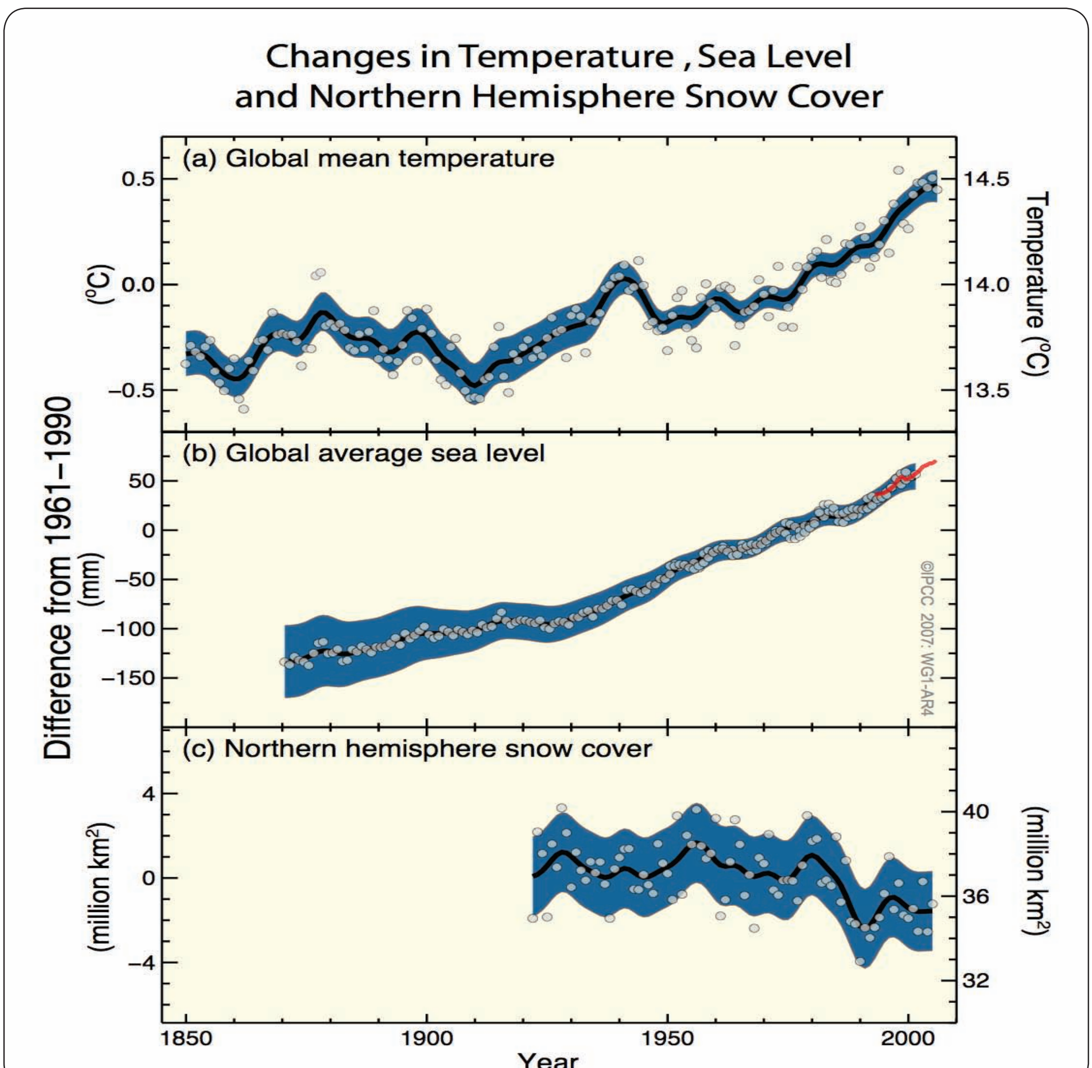
AN OVERVIEW OF CLIMATE CHANGE, CARBON TRADING : INTERNATIONAL STANDARDS

Mr. Sandeep Tripath
Director
Indian Council of Forestry Research and Education
Dehra Dun

1. Climate Change

- In a irreversible direction
- On an increasingly faster rate
- Mainly due to anthropogenic reasons

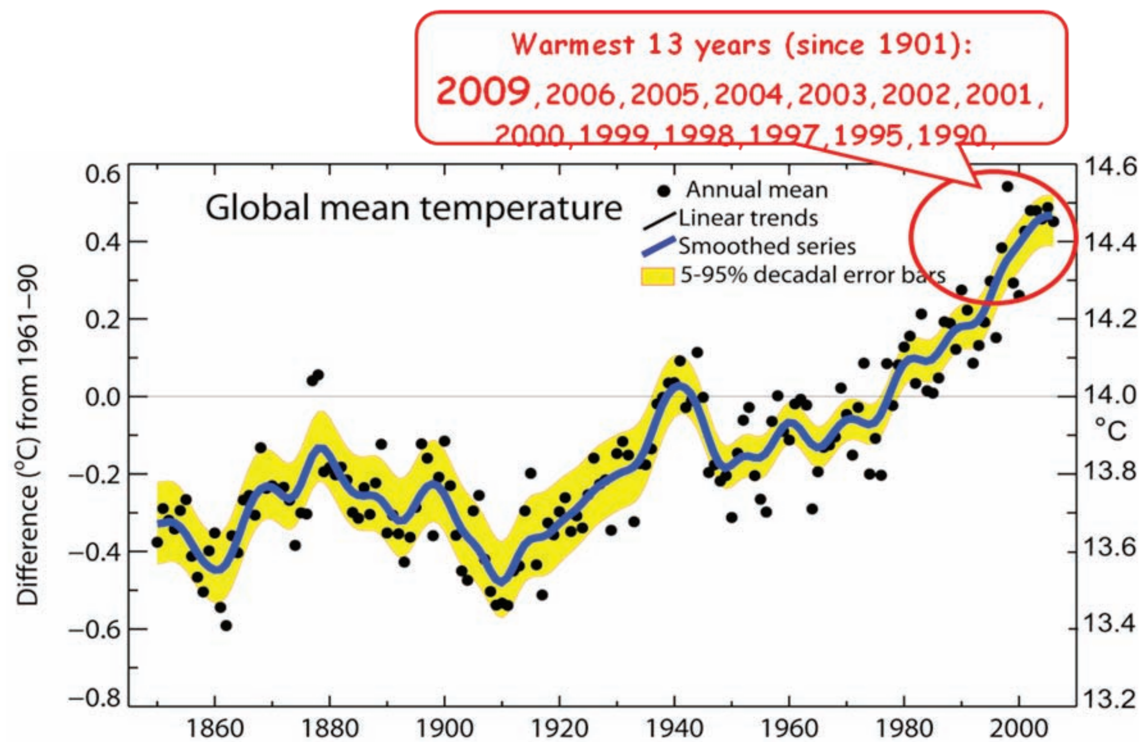
2. Direct Observations of Recent Climate Change

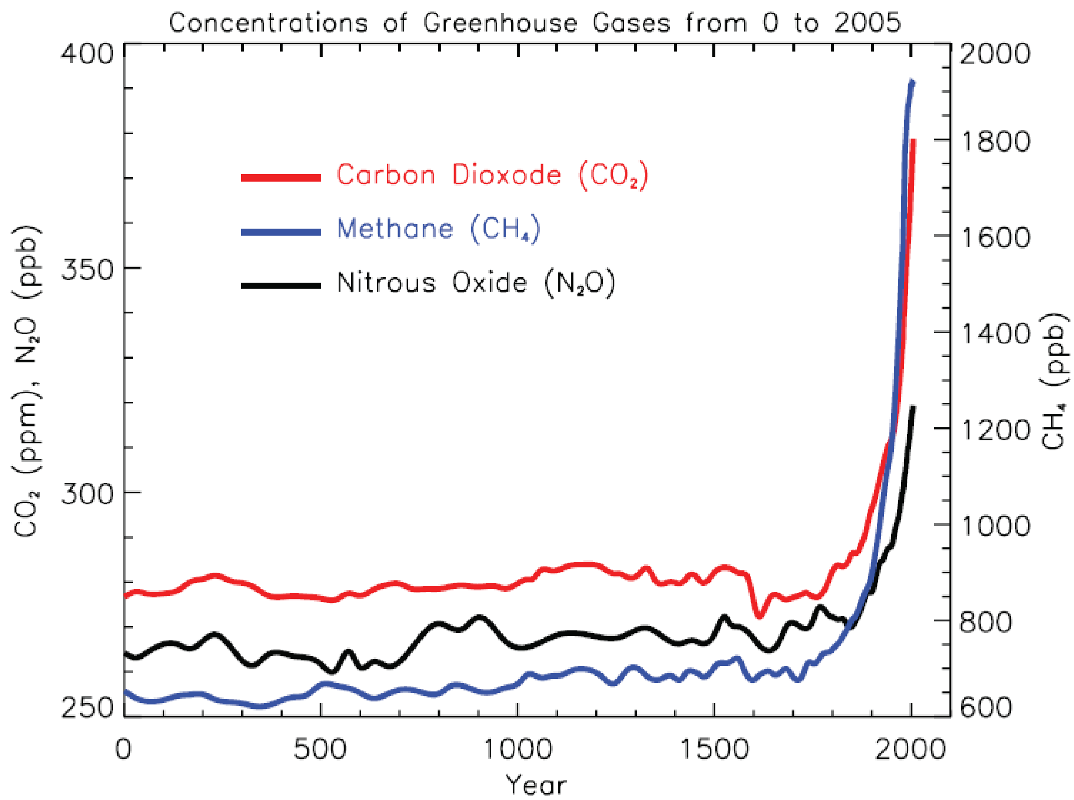


3. Indications of a Global Climate Change

- Global-average temperature increased by 0.74 ºC between 1906-2005, larger than corresponding trend of 0.6ºC for 1901-2000 given in TAR
- 1990s warmest decade and last 13 year, among 15 warmest years since 1850
- Global Sea level rise of 20 cm in last century.
  1.8 mm/yr during 1961-2003, faster during 1993-2001(@3.1 mm/yr)
- GHG emission up by 70 % between 1970-2004
- 10% reduction in snow cover ice since late 1960s

4. Global mean temperatures are rising faster with time





5. Climate Change: Future Variabilities

- Mean temperature projected to increase by 1.4 ºC to 5.8 ºC by 2100
- Biodiversity loss of 15-25% if warming exceeds 1.5 – 2.5 °C
- Increase in Sea level rise – 0.02 m by middle, and 0.15 m by 2100
- Increase in rainfall 15-40% (intense with high regional variability)
- Decrease in freshwater availability in arid & semi arid areas with 1/3 world's population(more than double) under water scarcity
- Increased flood hazard, from 1.4-1.6 billion in 1995 to 4.3-6.9 billion in 2050
- 30 % fall in agriculture production in India –tropics & Subtropics
- Enhanced natural disturbances such as fires, pests and extreme climatic events

6. Impact of Climate Change

- Impacts are worse - already more flood and drought prone and a large share of the economy is in climate sensitive sectors
- Lower capacity to adapt because of a lack of financial, institutional and technological capacity and access to knowledge
- Climate change is likely to impact disproportionately in the poorest countries, states and the poorest persons within states, exacerbating inequities in health status and access to adequate food, clean water and other resources.

7. Impact of Climate Change on Forest Ecosytems

- Increased risk of extinction and loss of biodiversity
  - Approximately 20-30% of species at risk if warming exceeds 1.5 – 2.5 °C (relative to 1980-1999)
  - Approximately 40-70% of species at risk if warming exceeds above 3.5 °C
- On forests and forest functions
  - Migration of species, flowering, pollination, bird arrival
- Likely changes structure and functions
  - Diversity,maintenance, productivity, carbon sequestration, water cycling, etc., projected
- Enhanced natural disturbances such as fires, pests and extreme climatic events

8. Sequestration Potential of Indian Forests

- Annual CO2 removal by forests 11.25% of India's GHG emission~ 100%Transport/ residential sector
- Carbon Stocks in 1995- 6,245 million tonnes
- Carbon Stock of World's Forests-638 Gt (FAO-07)
- Carbon Stocks in 2005- 6,662 million tonnes
- Annual Increment of 38 mt of C or 138 mt of CO2
- Valuation of carbon Stock-24000mt CO2
  -Rs. 6,00,000 crore @$US5
- Incremental Value of Carbon Stocks-Rs.6,000 crore

9. International Response Framework

- 1988: UN Intergovernmental Panel on Climate Change (IPCC)
  - Established by UN to assess technical information
- 4 Working Groups
  - WG-1 Physical basis of science
  - WG-2 Impact adaptation and vulnerability
  - WG-3 Climate Change mitigation
  - WG-4 GHG inventory
- Releases Assessment Reports (AR) since 1990
- Awarded Nobel peace prize for 2007

10. IPCC 4th Assessment Report

Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2 equivalent

• Energy Supply	25.9%
• Industry	19.4%
• Forestry	17.4%
• Agriculture	13.5
• Residential and	7.9%

Commercial building

- Waste and Wastewater 2.8%

11. International Response Framework

- 1992: Rio "Earth Summit" UN Framework Convention on Climate Change (UNFCCC) -21 March 1994 - entry into force
- Objectives- GHG stabilization, Food Security, Sustainable Economic & Social Development
- 1997: COP 3 "Kyoto Protocol"-Enforced on 16th February 2005
  - 41 Annex 1 parties (industrialized countries) are legally bound to reduce their GHG emission by 5.2 % before 2012
  - USA yet to ratify, Australia ratified in 2007
  - To reduce costs of reduction in overall emission of GHGs, 3 Market Based Mechanism

12. Per capita emissions and global share of emissions

Country	Per capita CO2 emissions (in tonnes)	% of global share of CO2 emissions
World	4.5	
OECD	11.5	
Developing Countries	2.4	
USA	20.6	20.9
UK	9.8	2
Germany	9.8	2.8
Japan	9.9	4.3
Canada	20	2.2
China	3.8	17.3
Brazil	1.8	1.1
South Africa	9.8	1.5
India	1.2	4.6

Source: HDR 2007

13. Market Based Mechanisms

(i) **Emission Trading (Article 17):** Allow the developed countries to transfer emissions credits to each other

(ii) **Joint Implementation (Article 6):** Implemented between two developed (Annex 1) countries. Credits obtained by investing countries are offset by debits to the country hosting the Project

(iii) **The Clean Development Mechanism (Article 12)**

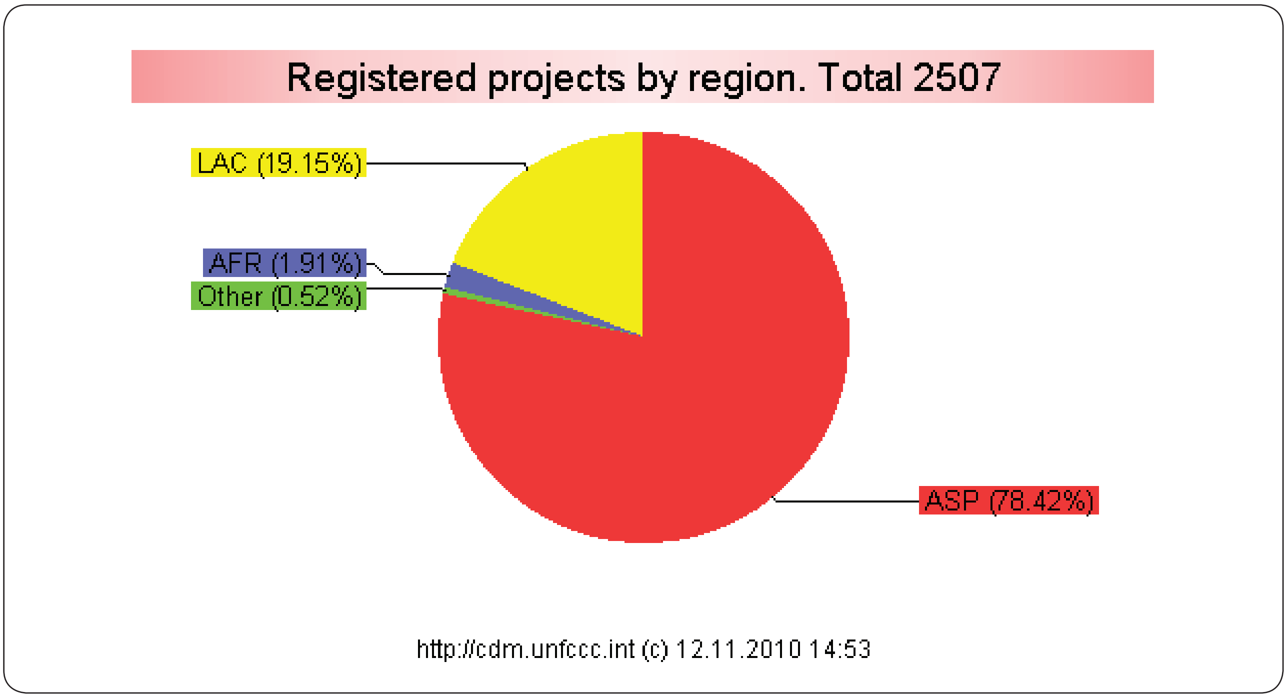
14. The Clean Development Mechanism (CDM)-Article 12

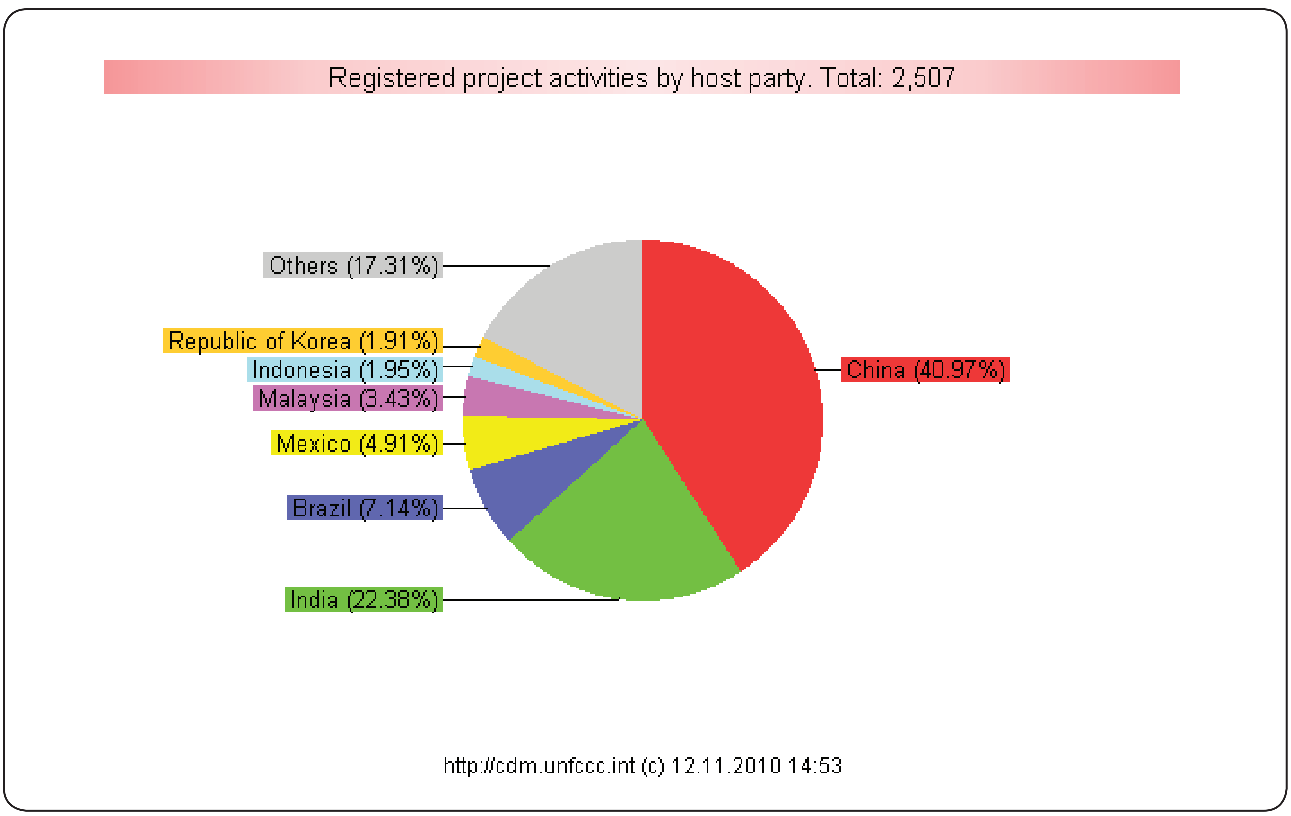
- To promote sustainable development by encouraging investments by Governments and Private firms in *environmental friendly projects in developing countries* that reduce or avoid emission.
- Implemented between Annex I and Non-Annex I countries in the geographic territory of Non-Annex countries
- Developed countries receive credit against their targets for emissions avoided by these projects at low cost.

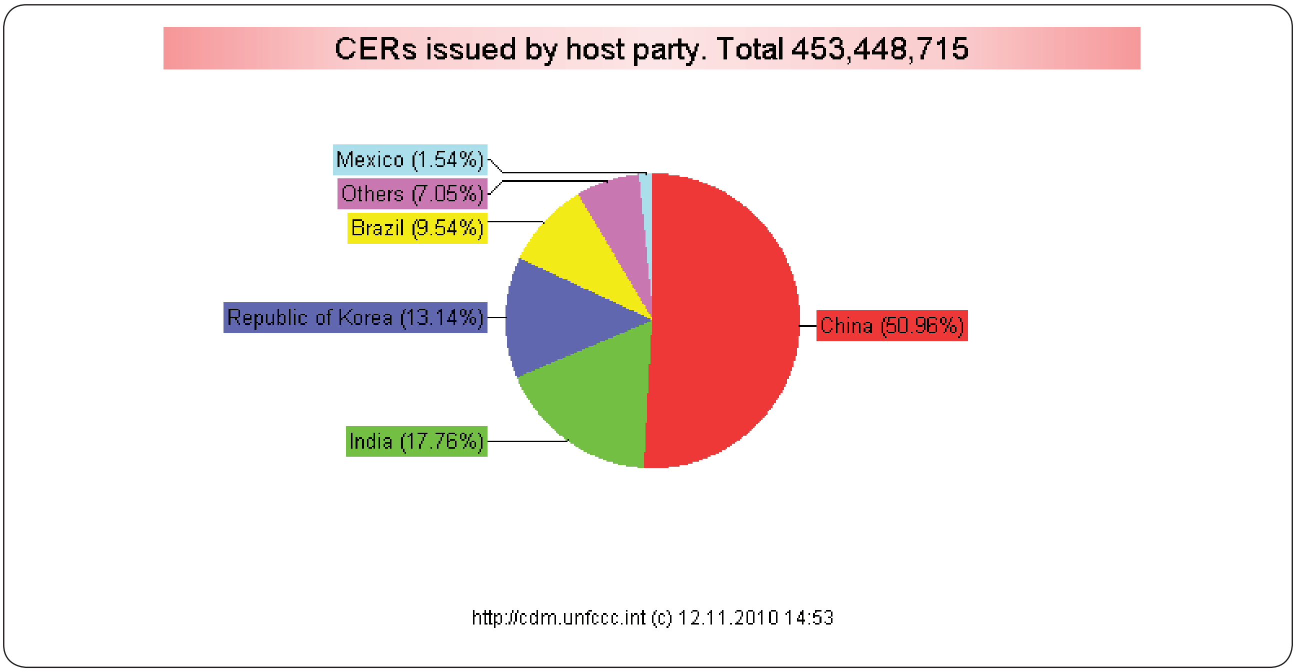
15. How CDM operates

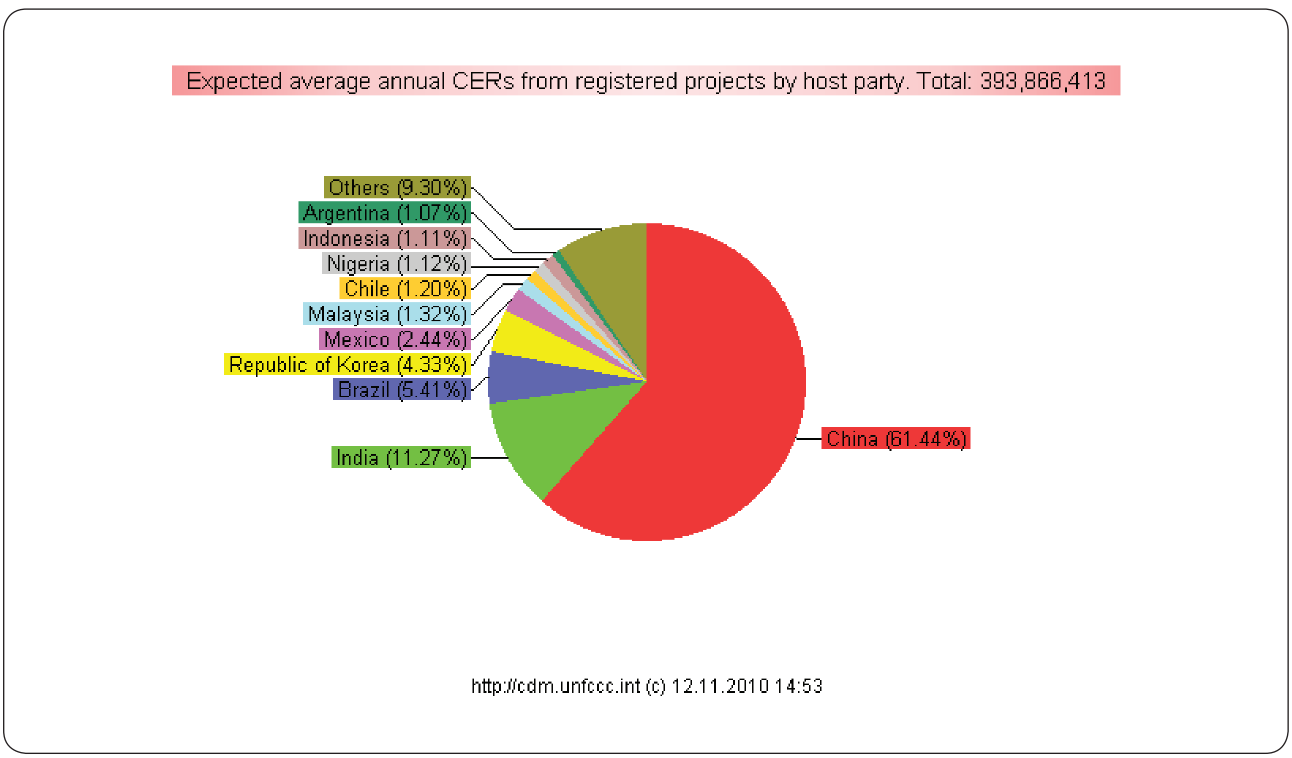
- As a result of Kyoto Protocol carbon has become a tradable commodity
- Any entity (foreign, domestic, joint venture, public, corporate, non-profit) may set up a project to produce any good (e.g. steel) or any service (e.g. transportation), in a non-Annex I Party
- One Tonne of CO_2 reduced through a CDM Project is known as a Certified Emission Reduction (CER) when issued by CDM EB and transferred to the buyer in Annex-I country which can be traded

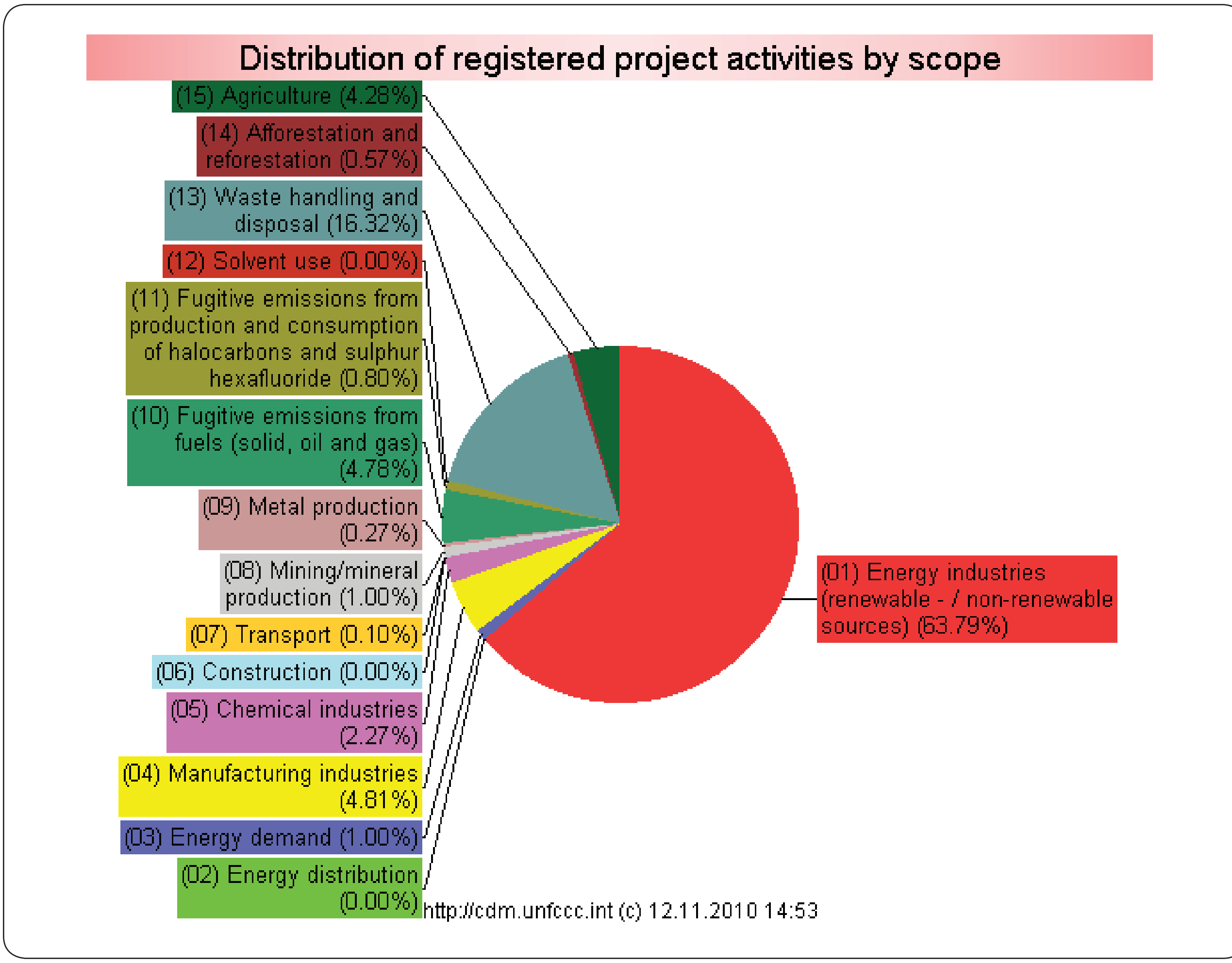
CDM project pipeline: > 4200
Expected CER by 2012: 2,900,000,000
Registered Projects: 2504 (525 from India)
A&R (Forestry):
16 methodologies approved
6 Small Scale A&R methodology approved
12 A&R Project registered- 3 from India


Registered projects by region. Total 2507
LAC (19.15%)
AFR (1.91%)
Other (0.52%)
ASP (78.42%)
http://cdm.unfccc.int (c) 12.11.2010 14:53


Registered project activities by host party. Total: 2,507
Others (17.31%)
Republic of Korea (1.91%)
Indonesia (1.95%)
Malaysia (3.43%)
Mexico (4.91%)
Brazil (7.14%)
India (22.38%)
China (40.97%)
http://cdm.unfccc.int (c) 12.11.2010 14:53


CERs issued by host party. Total 453,448,715
Mexico (1.54%)
Others (7.05%)
Brazil (9.54%)
Republic of Korea (13.14%)
India (17.76%)
China (50.96%)
http://cdm.unfccc.int (c) 12.11.2010 14:53

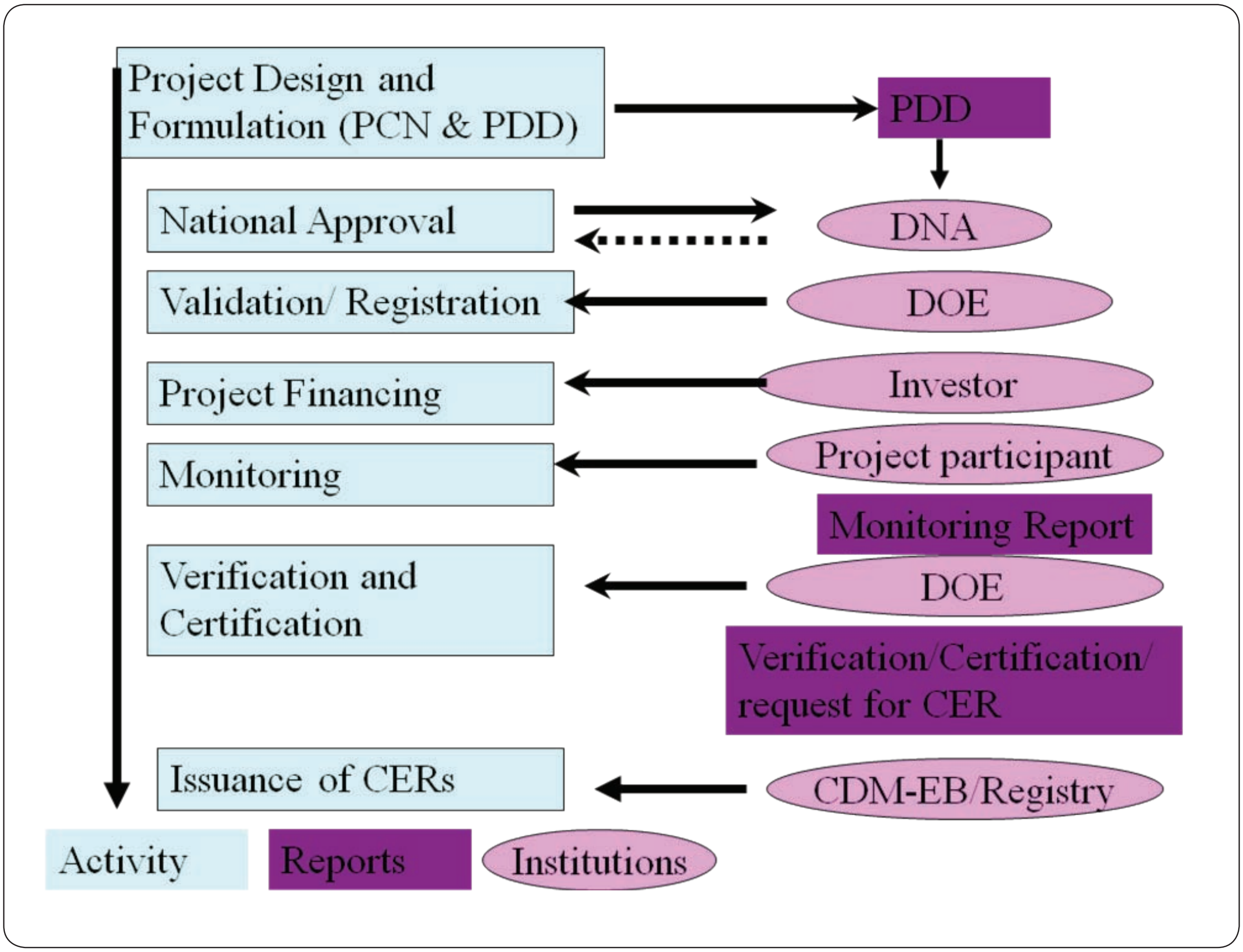

Expected average annual CERs from registered projects by host party. Total: 393,866,413
Others (9.30%)
Argentina (1.07%)
Indonesia (1.11%)
Nigeria (1.12%)
Chile (1.20%)
Malaysia (1.32%)
Mexico (2.44%)
Republic of Korea (4.33%)
Brazil (5.41%)
India (11.27%)
China (61.44%)
http://cdm.unfccc.int (c) 12.11.2010 14:53



16. Host Country Approval

- Emissions Additionality
- Sustainable Development
- Parties should have ratified Kyoto Protocol
- Voluntary participation

17. CDM Project cycle



18. Technological/Methodological Issues

- Additionality
  - Physical
  - Financial
- Baseline scenario
- Leakage
- Land Eligibility
- Project Developers (SFDS', Private) / DOE

19. For land use, land-use change and Forestry activities following definitions shall apply:

"Forest" is a

- **minimum area of land of 0.05 – 1.0 ha**

- **with tree crown cover of 10 – 30 per cent**
- **trees with the potential to reach a minimum height of 2 – 5 meters**

20. Forest Definition

India's original Forest definition:
Tree crown Cover 10-30% (30%)
Tree Height: 2-5 m (5m)
Minimum area: 0.05-1 ha (0.05ha)
Serious thought was given to this issue and changes were recommended:
UNFCCC changed the country forest definition as follows:
Tree crown Cover (15%)
Tree Height: (2m)
Minimum area: (0.05ha)

(a) **"Afforestation"** is direct human-induced conversion of land that has not been forested for a period of *at least 50 years* to forested land through planting, seeding and/or the human-induced promotion of natural seed sources

(b) **"Reforestation"** is direct human-induced conversion of non-forested land to forested land, *that did not contain forest on 31 December 1989* ,through planting, seeding and/or the human-induced promotion of natural seed sources

APPROVED A&R CDM PROJECTS

Date	Project Title	Host party	Other party	Methodology	Reductions*
10 Nov 2006	Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin	China	Italy Spain	AR-AM0001 ver. 2	25795
30 Jan 2009	Moldova Soil Conservation Project	Republic of Moldova	Netherlands	AR-AM 002 ver.1	179242
23 March 09	Small Scale Cooperative Afforestation CDM Pilot Project Activity on Private Lands Affected by Shifting Sand Dunes in Sirsa, Haryana	India		AR-AMS001 ver.4	11596
28 April 09	Cao Phong Reforestation Project	Viet Nam		AR-AMS 001 ver.4	2665

Date	Project Title	Host party	Other party	Methodology	Reductions*
5 June 09	Reforestation of severely degraded landmass in Khammam District of Andhra Pradesh, India under ITC Social Forestry Project	India		AR-AM0001ver.2	57792
11 June 09	Carbon sequestration through reforestation in the Bolivian tropics by smallholders of “The Federación de Comunidades Agropecuarias de Rurrenabaque (FECAR)”	Bolivia	Belgium	AR-AM0001ver.4	4341
21 August 09	Uganda Nile Basin Reforestation Project No.3	Uganda	Italy	AR-AM0001 ver.5	5564

APPROVED A&R CDM PROJECTS

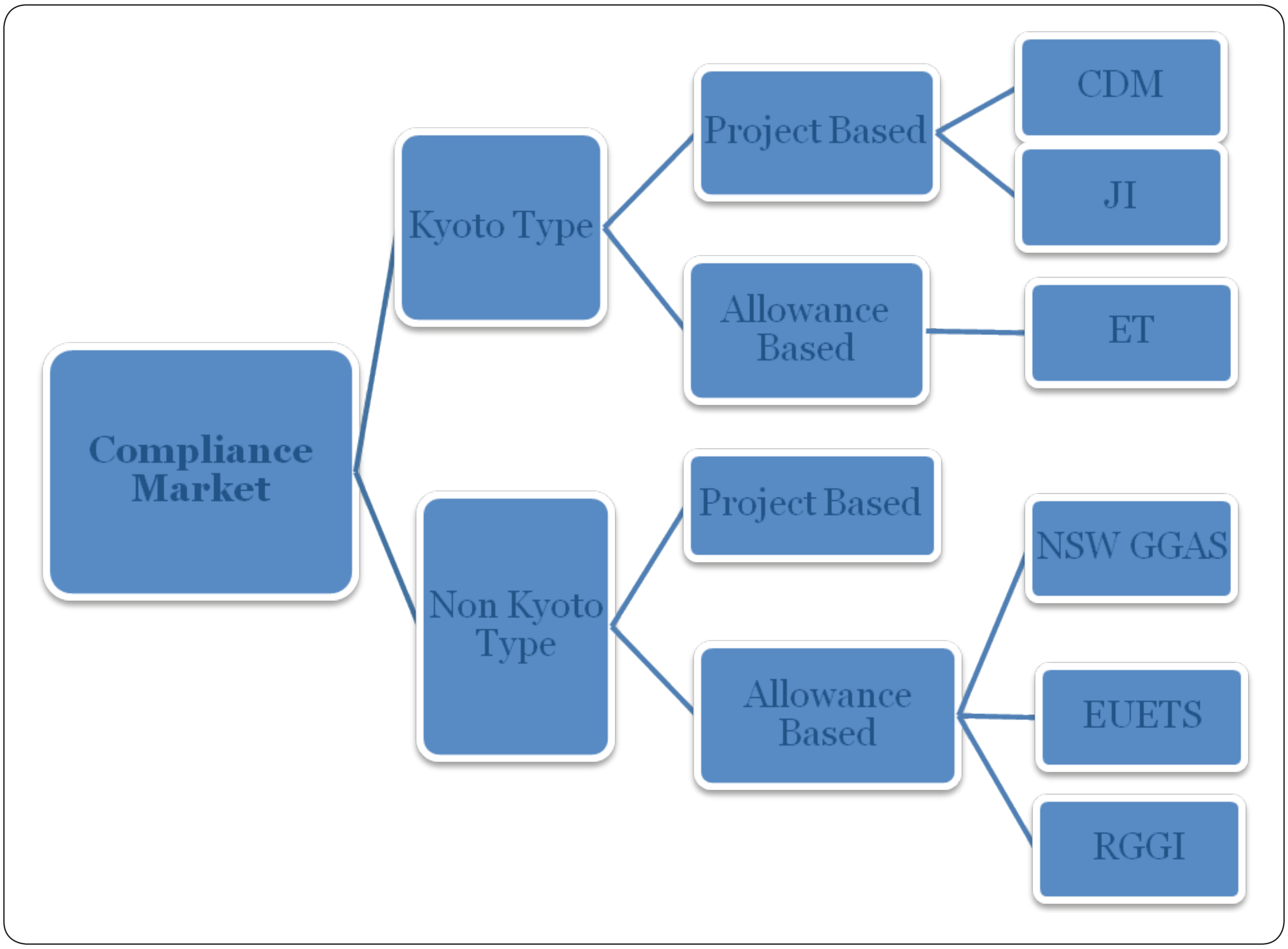
Date	Project Title	Host party	Other party	Methodo-logy	Reduc-tions*
06 Sept 09	Reforestation of croplands and grasslands in low income communities of Paraguari Department Paraguay	Paraguay	Japan	AR-AMS0001 ver. 4	1523
16 Nov 09	Afforestation and Reforestation on Degraded lands in Northwest Sichuan, China	China		AR-AM003 ver.3	23030

Date	Project Title	Host party	Other party	Methodo-logy	Reduc-tions*
16 Nov 09	Reforestation Sustainable production and carbon sequestration project in Jose Ignacio, Tavara's dry Forest, Peru	Peru		AR-AM 003 ver.4	48689
15 Jan 2010	The International Small Group and Tree plating Programme (TIST) Tamil Nadu India	India	UK and North Ireland	AR AMS 001 Ver .5	3594
Review	Reforestation as renewable source of wood supplies for industrial use	Brazil	Neterlands	AR-AM 0005 ver. 2	2569
07 Dec 09	Humbo Ethiopia assisted Natural Regeneration project	Ethiopia	Canada	AR-AM 00003 ver . 4	29343
02 Jan 10	Assisted Natural Regeneration of Degraded lands in Albania	Albinia	UK & N.Ireland	AR-AM 00003 ver . 4	22964

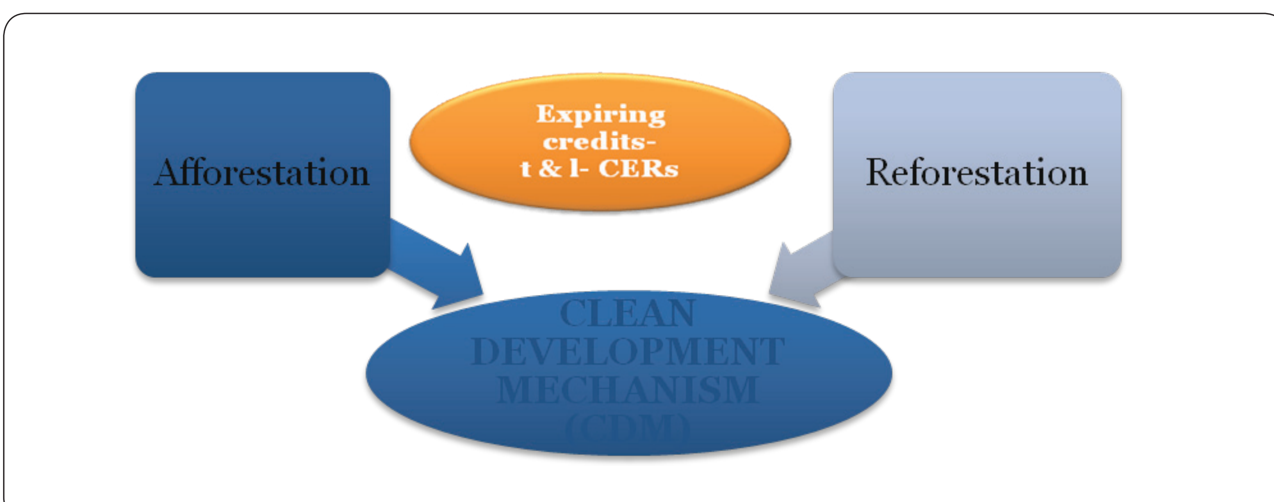
21. Carbon Markets

Compliance market: CDM (CER)
Voluntary markets: CCX (VER)
Institutional Buyers: World Bank (Different Funds) Ecosecurites, Banks
REDD+ Market may come after 2012

22. Compliance Market

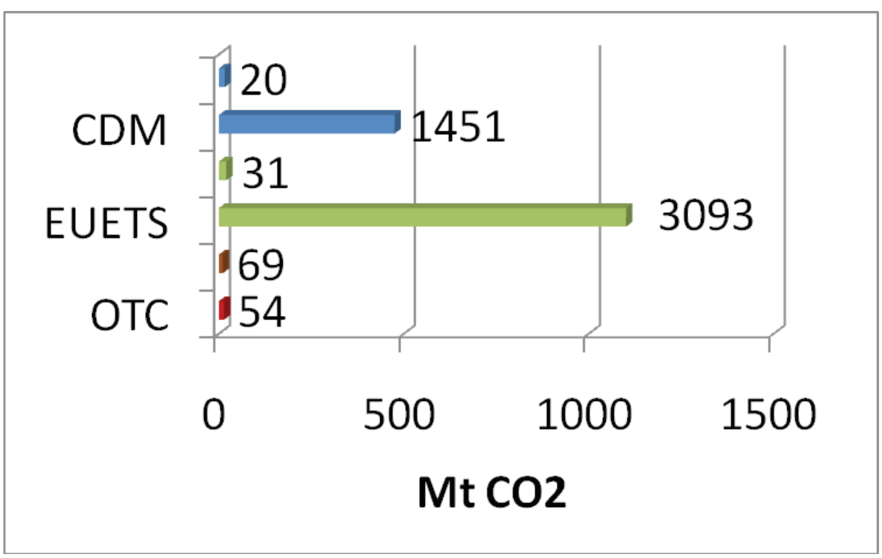


23. Eligible activities in compliance market



24. Eligible activities in voluntary market

25. International Carbon Market Trading 2008 - 4811 Mt CO_2



26. International Carbon Market Trading

- Compliance Market Total value - US$ 118 billion (1639 $MtCO_2$ e)
  - Compliance Allowance based market – US$ 92 billion (Mainly under the European Union Allowance Trading through ETS Kyoto Mechanism)
  - Compliance Project based market (through CDM and JI Kyoto Mechanism) – US$ 26 billion
- Voluntary Market Total value – US$ 9 Billion (23 $MtCO_2$)

27. Market Value of Carbon Credits

- Average CER price
  US$ 22 /tCO_{2eq}
- Average VER price
  US$ 4 /tCO_{2eq}
- Carbon offset credits price depend on
  - Market demand
  - Quality of credits
  - Nearness to end of 1st commitment period (2008-12), i.e. year 2012 etc.
- Prices expected to rise
  - Projected compliance shortfall of 3.3 billion tCO_{2e} for Kyoto Parties

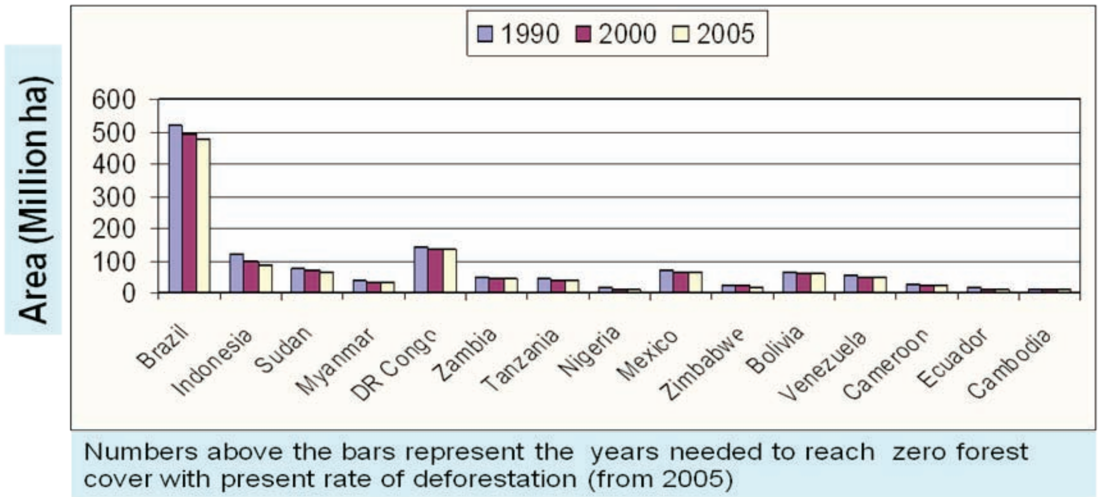
28. REDD+

- First Deliberated in COP – 11 at Montreal 2005
- Followed up by Workshops at Rome, Italy in August 2006 and Cairns, Australia in March 2007
- In COP – 12 at Nairobi, SBSTA 26 at Bonn India pleaded for incentives towards conservation measures also
- In COP -13 at Bali discussion on exiting & potential Policy Approaches, incentives & methodological issues
- In COP-14 at Poznan role on conservation & SMF recognized- REDD +
- Being deliberated under AWG-LCA of UNFCCC

29. Change in extent of Forest Cover and wooded lands 1990-2005 (Excluding Annex I Countries, Data Source: FAO, 2005)

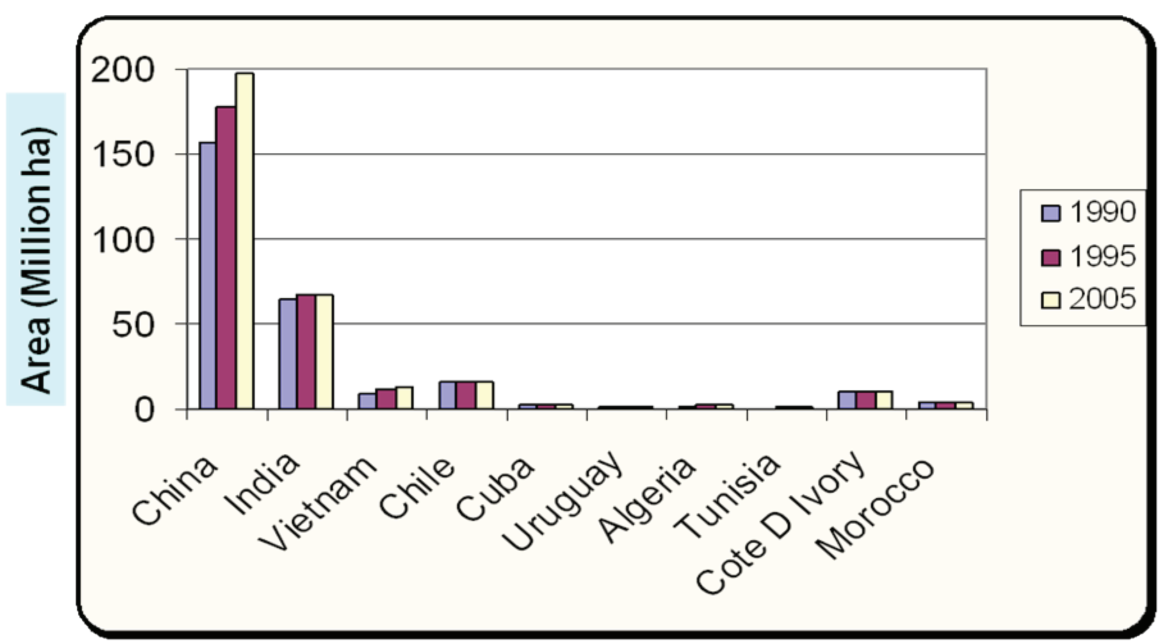
SL. No.	Countries	Number of Countries	Area 1,000 ha		Annual Change	
			1990	2005	1,000 ha/ year	%
1	Non Annex countries with increasing forest cover and other woodeds lands	27	443,092	479,624	2,436	+0.55
2	Non Annex countries with decreasing forest cover and other wooded lands	74	2484,855	2283,436	13,430	-0.54
3	Countries with negligible or No change	90	-	-	-	-

30. Nations: Decreasing Forest Cover Top (15 Non Annex 1 Countries)



Source: FRA 2005 (FAO 2005)

31. Nations: Increasing Forest Cover (Top 10 Non Annex 1 Countries)



Source: FRA 2005 (FAO, 2005)

32. Incentives Claim: India

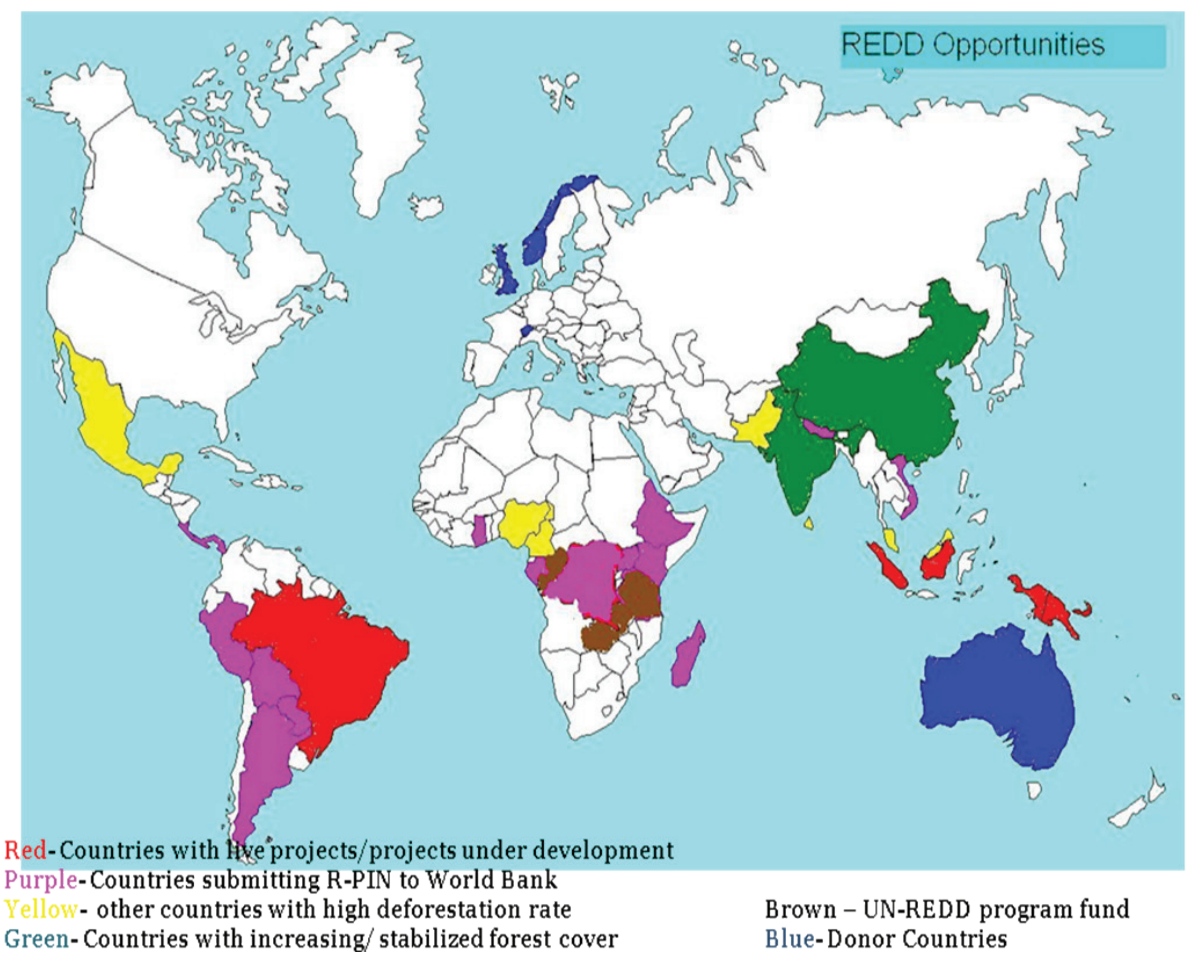
Proposed policy approach of Compensated Conservation seeks incentive for

1. incremental stocks of 0.96 GtC between 2006-2030 (projected increase from 8.79 GtC in 2006 to 9.75 GtC in 2030)
2. baseline stocks of 8.79 GtC as on 2006

33. REDD – Financial Mechanism

- REDD + intend to operate within the framework of international conventions, protocols, rules and regulations relating to climate change, but outside the CDM of Kyoto Protocol
- Financial mechanism linked to verifiable C- increment
- ODA, GEF, WB or Climate Change Adaptation Fund enhanced and made available for such incentives

34. REDD outreach potential



Technical Session 2

UNFCCC GUIDELINES FOR FOREST CARBON POOLS -TIER I, II & III

Mr. R.S. Gill,
Joint Director (TFI)
Forest Survey of India, Dehra Dun

1. Introduction

1.1 Changes in carbon stocks in different carbon pools provide a measure of greenhouse gas emissions and removals. The carbon pools are biomass (above-ground and below-ground), dead organic matter (Dead Wood and Litter) and soil. These pools are not only in constant interface with the atmosphere but also with each other. Guidelines are necessary to facilitate the measurement of pools without omissions or double-counting in a way that brings uniformity in global measurement endeavors. UNFCCC recognizes that the exactness expected from the measurement of a carbon pool needs to be counterweighed against the significance of that pool in a particular national circumstance and the resources the country can set aside for its measurement. For this reason a three tier system of guidelines for the measurement of carbon pools has been created.

1.2 The three pools are arranged in an ascending order of disaggregation, thoroughness and costs. Tier I is the base methodology relying on many assumptions and default values. Tier II relies on country-specific data. Tier III is more detailed based on models and allometric equations. Guidelines may or may not exist for all tiers of measurements in relation to all pools. These limitations should be borne in mind by countries while selecting the tier most suitable for a particular measurement.

1.3 Tier 1 relies heavily on default measurements. Because of the limitations in deriving default data sets, Tier I methods include the following simplifying assumptions:

- Changes in below-ground biomass C stocks are assumed to be zero
- Dead wood and litter pools are often lumped together as 'dead organic matter'
- Dead organic matter stocks are assumed to be zero for non-forest land use categories

1.4 We also have to factor in the history and evolution of the present forest land. Although the measurements pertain to forests, all existing forest lands may not have been forests at all times. There would be lands that were converted to forest land from cropland, grassland, wetlands, settlements and other lands. The conversion from a different category of land to forest land introduces new considerations in the measurement of carbon stocks. For this we have to create two categories of Forest Land Remaining Forest Land and Land Converted to Forest Land. Forest Land Remaining Forest Land is a land that has been forest land long enough for soil carbon levels to reach a new level following land-use change. Until the time the soil carbon in a new forest reaches a stable level, that land stays in the category of Land Converted to Forest Land. The default value for the length of time needed for stable carbon levels to arrive is 20 years. Of course, in the law of nature 20 years cannot be a rigid deadline. The transition period to reach new carbon levels would be shorter for warmer climate than for colder climate. A time period fixed according to the circumstances in a particular country would be a more accurate figure. After the transition period is past, the converted lands become Forest Land Remaining Forest Land. As for those lands for which no data is available on land conversion and the period involved, the default assumption is that the land belongs to the category Forest Land Remaining Forest Land.

1.5 Thus our study has different permutations that involve the carbon pools and the categorization of land as Forest Land Remaining Forest Land and Land Converted to Forest Land. UNFCCC guidelines in relation to each pool and category of land are to be examined separately. In the analysis of each pool below, we first look at general considerations and parameters involved in measuring carbon stocks in Forest Land Remaining Forest Land. The effect of conversion from other land uses to forests is subsequently reviewed.

2. Biomass

2.1 Biomass gain comes from growth in above-ground biomass and below-ground biomass. Losses occur from wood felling or harvest, fuelwood gathering, and losses from natural disturbances from managed land such as fire, insect outbreaks and extreme weather events like hurricanes or flooding. When losses occur, below-ground biomass is also reduced and transformed into dead organic matter.

2.2 There are two methods for estimating carbon stock changes in biomass. The **Gain-Loss Method** measures the difference between the annual increase in carbon stocks due to biomass growth and the annual decrease in carbon stocks due to biomass loss for each land sub-category. The **Stock-Difference Method** considers biomass carbon stock inventories for a given land area at two points in time and obtains the result by subtracting one figure from the other and dividing the result by the number of years between the inventories. The Stock-Difference Method will be applicable to countries that have national inventory systems for forests and other land-use categories, where stocks of different biomass pools are measured at periodic intervals. The Gain-Loss Method, on the other hand, can be used by countries that do not have national inventory systems designed for estimating woody biomass stocks. The decision about whether to use Gain-Loss Method or Stock-Difference Method to measure biomass change shall be a matter of judgment based on national inventory systems and availability of data and conversion and expansion factors. The Gain-Loss Method lies at the core of Tier I methodology. Default values are available for calculation of increment and losses to estimate stock changes in biomass using Tier I. Gain-Loss Method can also be used in Tier 2 and Tier 3 methodologies using country-specific activity data. The Stock-Difference Method requires greater resources and many countries may not have national inventory systems for forests and other land-use categories. This method is suitable for countries adopting a Tier 3 and in some cases a Tier 2 approach, but may not be suitable for countries using a Tier 1 approach due to limitations of data.

2.3 The above-ground biomass growth for Tier 1 may be obtained from default values for naturally regenerated trees or broad categories of plantations. For Tier 2 and Tier 3 the net annual increment is multiplied either with basic wood density D and Biomass Expansion Factor (BEF) or directly with Biomass Conversion and Expansion Factor (BCEF) to obtain the above-ground biomass increment. Below-ground carbon stock changes are measured by introducing a factor R, which is the ratio of below-ground biomass to above ground biomass for a specific vegetation type. For Tier 1 method R must be set to zero if assuming no changes of below-ground biomass allocation. For Tier 3, nationally or regionally determined values of R or regression models may be used.

2.4 To measure the carbon loss in biomass due to wood harvest, fuelwood removal and disturbances like fire, storms and insects and diseases, the Tier 1 assumption is that all loss of carbon due to disturbance is emitted to the atmosphere in the year of the disturbance. Tier 2 and Tier 3 methods assume that some of this carbon is emitted immediately and some is added to the dead organic matter pools or the Harvested Wood Products. To ensure that no double counting occurs in Tier 1 inventories where biomass in areas affected by disturbances has been already assumed to be released to the atmosphere, salvage of wood from areas affected by disturbances must be subtracted from biomass.

3. Land Converted to Forest Land

3.1 Tier 1 employs a default assumption that there is no change in initial biomass carbon stocks due to conversion. No estimate of change in carbon stocks due to conversion is required for Tier 1 calculation. This assumption can be applied if the data on previous land uses is not available. If the previous land use on a converted forest is known, then the Tier 2 method can be used. Tier 2 (and 3) methods use nationally derived data for more disintegrated approaches. An additional parameter is introduced to measure change in biomass carbon stocks on Land Converted to Forest Land. This is the initial change in carbon stocks in biomass resulting from the process of conversion itself. The initial change in carbon stock due to conversion may occur due to biomass withdrawal through land clearing, restocking and other human-induced activities prior to natural or artificial regeneration.

4. Dead Organic Matter

4.1 Dead Organic Matter comprises dead wood and litter. The Tier 1 assumption for dead wood and litter pools is that these stocks are not changing over time if the land remains within the same land-use category. Countries using Tier 1 methods report zero change in carbon stocks. Thus $CO2$ emissions resulting from the combustion of dead organic matter during fire are not reported, nor are the increases in dead organic matter carbon sinks in the years following the fire. To estimate the carbon dynamics of dead organic matter, countries can use higher Tier methods. The change in carbon stocks is measured by calculating the difference between the average annual transfer of biomass into dead organic matter due to processes and disturbances and the carbon loss out of dead organic matter due to decay and disturbance. Hence, Tier 2 and Tier 3 methods require estimates of the transfer and decay rates as well as activity data on harvesting and disturbances and their impact on the DOM pool. Mortality is to be counted as an addition to the dead wood pool for Tier 2 and Tier 3 methods.

5. Land Converted to Forest Land

5.1 The Tier 1 assumption is that carbon stocks in dead wood and litter pools in non-forest land are zero, and that carbon in dead organic matter pools increases linearly to the value of mature trees over the specified period (default = 20 years). After 20 years, the area converted enters the category Forest Land Remaining Forest Land and no further DOM changes are assumed in a Tier 1 approach. Inventories using a Tier 1 method assume that all carbon contained in biomass killed during conversion (less the harvested wood removal) is emitted directly to the atmosphere and none is added to the dead wood and litter pools. Tier 1 methods also assume that dead wood and litter pool carbon losses occur entirely in the year of transition.

5.2 The Tier 1 assumption of zero carbon stocks in dead wood and litter pools in non-forest lands needs a closer look. Empirical evidence shows this may not be the case. Some of the non-forest land use categories as Wetlands, Settlements and Croplands can have significant carbon stocks in the DOM pool. The assumption that carbon stocks in dead wood and litter pools of non-forest land use categories are zero would be highly inaccurate in some agro-forestry systems and settlements with substantial forest cover. It is a good practice to assess whether the assumption of zero DOM pool sizes is justified for the specific case of Land Converted to Forest Land under consideration. Similarly, the default length of the transition time has its own complications. If the time required to accumulate DOM pools is longer than the default period, the Tier 1 assumption may overestimate the rate of carbon accumulation. Higher Tier methods can specify the initial DOM pool sizes and quantify the length of the transition period during which DOM pools are changing as a result of transition to Forest Land. It is a good practice to stratify areas converted to Forest Land according to the prior land use, the methods used during the conversion and the productivity and characteristics of the forest that is growing. All these factors influence the magnitude and rate of change of carbon stock in the DOM pools on Land Converted to Forest Land. The length of transition periods for litter and dead wood carbon stocks may also be decided nationally. In practice, litter pools can stabilize more quickly than dead wood pools. Countries are also encouraged to select DOM stock values at maturity that adequately reflect national circumstances.

6. Soils

6.1 Soils contain both organic and inorganic forms of carbon. However, land use and management typically has a larger impact on organic C stocks. Organic soils have a minimum of 12-20% organic matter by mass. All other soils are mineral soil types. Mineral soils as a carbon pool are influenced by land use and management activities. Soil carbon inventories for mineral soil include estimation of soil organic C stock changes. In organic soils, the stored carbon decomposes when conditions become aerobic during soil drainage. Drainage of organic soils typically releases CO2 to the atmosphere. Countries can choose different tiers to prepare estimates for mineral soils and organic soils.

7. Mineral soils

7.1 For Tier 1 method, soil organic C stocks for mineral soils are computed to a default depth of 30 cm. A large proportion of input of soil organic C in forest soils is from above-ground litter. Hence, soil organic matter tends to concentrate in the upper soil horizons, with roughly half the soil organic C in the upper 30 cm layer. The carbon in this upper zone is often the most chemically decomposable and the most directly exposed to natural and anthropological disturbances. For this reason, a Tier 1 default depth of 30 cm is chosen (greater depth can be used at Tier 2). The default method in Tier 1 is based on changes in soil C stocks over a finite period of time. The carbon stock after the management change is measured relative to the carbon stock in a reference condition. For doing this, the first assumption made is that soil organic C will reach a stable value over time specific to the soil, climate, land use and management practices. The second assumption is that the transition of soil organic C stocks to a new equilibrium stage shall be linear. This assumption provides a good approximation over a multi-year inventory period. Stock change factors are assigned according to the land use and management activities to obtain the values of Soil Organic Carbon (SOC) for the first and last year of each inventory time period from the default values of SOC for different climatic regions and soil types.

Tier 2 methodology allows an inventory to incorporate country-specific data while using the default equations of Tier 1.

7.2 Tier 1 and 2 methodologies view the impact of land use and management on soil C stocks as a linear shift from one equilibrium state to another. However, soil C stocks typically do not exist in an absolute equilibrium state or change in a linear manner through a transition period. Tier 3 addresses this non-linearity with more advanced models and by developing a measurement based inventory with a monitoring network.

8. Organic soils

8.1 Currently only C emissions due to drainage of forest organic soils are addressed in Tier 1. The basic methodology for estimating C emissions from organic soils is to assign an annual emission factor that estimates the loss of C following drainage. Drainage stimulates oxidation of organic matter previously built up under a largely anoxic environment. The Tier 2 approach for CO2 emissions associated with drainage of organic soils incorporates country-specific information into the inventory to estimate the emissions. Tier 2 uses the same procedural steps for calculation as provided for Tier 1. In Tier 3, CO2 emissions attributed to land use and management of organic soils are estimated with a model or measurement based approach.

9. Land Converted to Forest Land

9.1 For Tier 1 approach in mineral soils, the initial (pre-conversion) soil organic C stocks SOC(0-T) and C stocks in the last year of the inventory time period SOC(0) are determined from the common set of reference soil organic C stocks SOC(REF) and default values as appropriate for both pre- and post-conversion land use and management systems. The Tier 2 approach uses the same equation but involves country or region specific reference C stocks and/or stock change factors. Tier 3 approach will involve more detailed and country-specific models.

9.2 For organic soils that are drained, the annual carbon loss will be calculated using a constant emission factor in Tier 1 and 2 approach. Tier 3 approach will involve country-specific models. Constant emission rate factors per se are less likely to be estimated in favor of variable rates that more accurately capture land use and management effects.

Technical Session 3

USE OF GPS AND IT APPLICATIONS IN FOREST INVENTORY

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1. The Global Positioning System

1.1 The **Global Positioning System** (**GPS**) is a space-based global navigation satellite system that provides reliable location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible by anyone with a GPS receiver. In addition to GPS other systems are in use or under development. The Russian GLObal NAvigation Satellite System (GLONASS) is for use by the Russian military. There are also the planned Chinese Compass navigation system and Galileo positioning system of the European Union (EU). GPS was created and realized by the U.S. Department of Defense (DOD) and was originally run with 24 satellites. It was established in 1970s to overcome the limitations of previous navigation systems.

1.2 While originally a military project, GPS is considered a *dual-use* technology, meaning it has significant military and civilian applications. GPS has become a widely used and useful tool for commerce, scientific uses, tracking and surveillance. GPS's accurate timing facilitates everyday activities such as banking, mobile phone operations, and even the control of power grids. Farmers, surveyors, geologists and countless others perform their work more efficiently, safely, economically, and accurately

2. Parts of GPS

2.1 **GPS consists of three parts** namely (a) the space segment, (b) the control segment, and (c) the user segment. The U.S. Air Force develops, maintains, and operates the space and control segments. GPS satellites broadcast signals from space, which each GPS receiver uses to calculate its three-dimensional location (latitude, longitude, and altitude) plus the current time.[25]

(a) **The space segment** is composed of 24 to 32 satellites in medium Earth orbit and also includes the payload adapters to the boosters required to launch them into orbit.

GPS Satellites

Name: NAVSTAR Manufacturer: Rockwell International
Altitude: 10,900 nautical miles Weight: 1900 lbs. (in orbit)

Size: 17 ft with solar panels extended Orbital Period: 12 hours
Orbital Plane: 55 degrees to equatorial plane.
Planned Lifespan: 7.5 to 10years

(b) **The control segment** is composed of a master control station, an alternate master control station, and a host of dedicated and shared ground antennas and monitor stations. The user segment is composed of hundreds of thousands of U.S. and allied military users of the secure GPS Precise Positioning Service, and tens of millions of civil, commercial, and scientific users of the Standard Positioning Service.

The MCS can also access U.S. Air Force Satellite Control Network (AFSCN) ground antennas (for additional command and control capability) and NGA (National Geospatial-Intelligence Agency) monitor stations. The flight paths of the satellites are tracked by dedicated U.S. Air Force monitoring stations in Hawaii, Kwajalein, Ascension Island, Diego Garcia, Colorado Springs, Colorado and Cape Canaveral, along with shared NGA monitor stations operated in England, Argentina, Ecuador, Bahrain, Australia and Washington DC.

GPS receivers come in a variety of formats, from devices integrated into cars, phones, and watches, to dedicated devices such as those shown here from manufacturers Trimble, Garmin and Leica.

(c) **The user segment** is composed of hundreds of thousands of U.S. and allied military users of the secure GPS Precise Positioning Service, and tens of millions of civil, commercial and scientific users of the Standard Positioning Service. In general, GPS receivers are composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly stable clock (often a crystal oscillator). They may also include a display for providing location and speed information to the user. A receiver is often described by its number of channels, typically have between 12 and 20 channels which signifies how many satellites it can monitor simultaneously.

3. How GPS works

I. The basis of GPS is “triangulation” from satellites.
II. To “triangulate,” a GPS receiver measures distance using the travel time of radio signals.
III. To measure travel time, GPS needs very accurate timing, which it achieves with some tricks.
IV. Along with distance, it is also needed to know exactly where the satellites are in space. High orbits and careful monitoring are the secret.
V. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

The whole idea behind GPS is to use satellites in space as reference points for locations on earth. By measuring our distance from three satellites very accurately we can “triangulate” our position anywhere on earth.

4. The Big Idea

4.1 Suppose we measure our distance from a satellite and find it to be 11,000 miles. Knowing that we're 11,000 miles from a particular satellite narrows down all the possible locations we could be in the whole universe to the surface of a sphere that is centred on this satellite and has a radius of 11,000 miles.

4.2 Next, say we measure our distance to a second satellite and find out that it's 12,000 miles away. That tells us that we're not only on the first sphere but we're also on a sphere that's 12,000 miles from the second satellite. Or in other words, we're somewhere on the circle where these two spheres intersect. If we then make a measurement from a third satellite and find that we're 13,000 miles from that one, that narrows our position down even further, to the two points where the 13,000 mile sphere cuts through the circle that's the intersection of the first two spheres. So by ranging from three satellites we can narrow our position to just two points in space. To decide which one is our true location we could make a fourth measurement. But usually one of the two points is a ridiculous answer (either too far from Earth or moving at an impossible velocity) and can be rejected without a measurement. A fourth measurement does come in very handy for another reason which will be dealt later. Next we'll see how the system measures distances to satellites.

5. Triangulation : At a Glance

I. Position is calculated from distance measurements (ranges) to satellites.
II. Mathematically we need four satellite ranges to determine exact position.
III. Three ranges are enough if we reject ridiculous answers or use other tricks.
IV. Another range is required for technical reasons to be discussed later.

6. The Big Idea Mathematically

In a sense, the whole thing boils down to the basic "velocity x travel time" math concept:
Velocity (60 mph) x Time (2 hours) = Distance (120 miles)
In the case of GPS we're measuring a radio signal so the velocity is going to be the speed of light or roughly 186,000 miles per second.

7. The problem is measuring the travel time

1.1 The timing problem is tricky. First, the times are going to be awfully short. If a satellite were right overhead the travel time would be something like 0.06 seconds. So we're going to need some really precise clocks.

1.2 Since measuring the travel time of a radio signal is the key to GPS, our stop watches are of no use, because even if their timing is off by just a 1000^{th} of a second, at the speed of light, that translates into almost 200 miles of error! However satellite timing is almost perfect because they have incredibly precise atomic clocks on board.

8. But what about receivers on the ground ?

1.1 We have to remember that both the satellite and the receiver need to be able to precisely synchronize their pseudo-random codes to make the system work. If our receivers needed atomic clocks (which cost upwards of $50,000 to $100,000) GPS would be a unaffordable technology. Luckily the designers of GPS came up with a brilliant idea that lets us get by with much less accurate clocks in our receivers. This trick is one of the key elements of GPS and as an added side benefit it means that every GPS receiver is essentially an atomic-accuracy clock.

1.2 The secret to perfect timing is to make an extra satellite measurement. If three perfect measurements can locate a point in 3-dimensional space, then four imperfect measurements can do the same thing.

9. Extra Measurement to take of Timing Errors

1.1 If our receiver's clocks were perfect, then all our satellite ranges would intersect at a single point (which is our position). But with imperfect clocks, a fourth measurement, done as a cross-check, will never intersect with the first three.

1.2 So the receiver's computer understands that there is an error in its measurements. I must not be perfectly synced with universal time.

1.3 Since any offset from universal time will affect all of our measurements, the receiver looks for a single correction factor that it can subtract from all its timing measurements that would cause them all to intersect at a single point.

1.4 That correction brings the receiver's clock back into sync with universal time, and you've got atomic accuracy time right in the palm of your hand.

1.5 Once it has the correction it applies to all the rest of its measurements leading to precise positioning. One consequence of this principle is that any decent GPS receiver will need to have at least four channels so that it can make the four measurements simultaneously.

1.6 With the pseudo-random code as a rock solid timing sync pulse, and this extra measurement trick to get us perfectly synced to universal time, we have got everything we need to measure our distance to a satellite in space.

1.7 But for the triangulation to work we not only need to know distance, we also need to know exactly where the satellites are.

10. Getting Perfect Timing

I. Accurate timing is the key to measuring distance to satellites.

II. Satellites are accurate because they have atomic clocks on board.

III. Receiver clocks don't have to be too accurate because an extra satellite range measurement can remove errors.

The errors are usually very slight but if you want great accuracy they must be taken into account.

11. Random Code

11.1 The Pseudo Random Code (PRC, shown above) is a fundamental part of GPS. The signal is so complicated that it almost looks like random electrical noise. Hence the name "Pseudo-Random." There are several good reasons for that complexity: First, the complex pattern helps make sure that the receiver doesn't accidentally sync up to some other signal. The patterns are so complex that it's highly unlikely that a stray signal will have exactly the same shape. Since each satellite has its own unique Pseudo-Random Code this complexity also guarantees that the receiver won't accidentally pick up another satellite's signal. So all the satellites can use the same frequency without jamming each other. And it makes it more difficult for a hostile force to jam the system. In fact the Pseudo Random Code gives the DoD a way to control access to the system.

11.2 But there's another reason for the complexity of the Pseudo Random Code, a reason that's crucial to making GPS economical. The codes make it possible to use "information theory" to "amplify" the GPS signal. And that's why GPS receivers don't need big satellite dishes to receive the GPS signals.

12. Satellite Positions

I. To use the satellites as references for range measurements we need to know exactly where they are.
II. GPS satellites are so high up their orbits are very predictable.
III. Minor variations in their orbits are measured by the Department of Defense.
IV. The error information is sent to the satellites, to be transmitted along with the timing signals

13. Measuring Distance

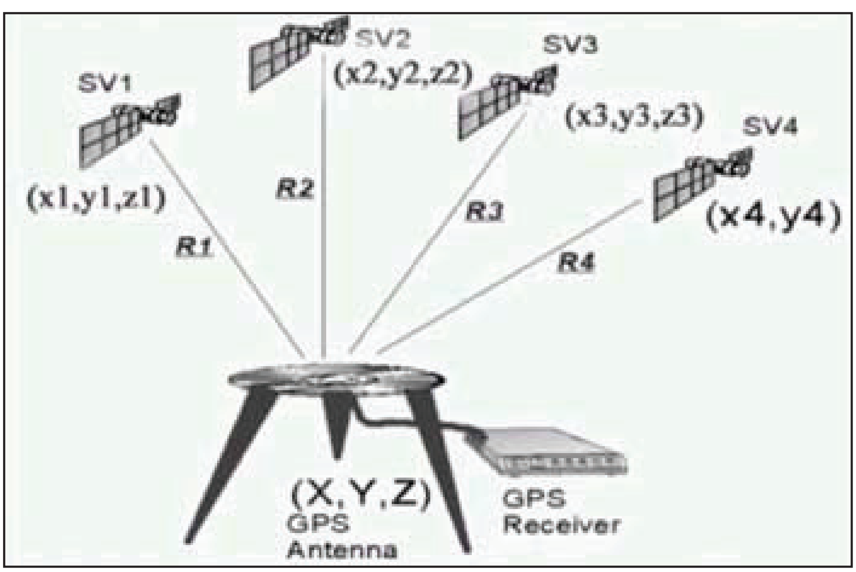


Fig.3: Calculation of Position

A GPS receiver determines its position by using the signals that it observes from different satellites. Since the receiver must solve for its position (X, Y, Z) and the clock error (x), four SVs are required to solve receiver's position using the following four equations:

$R_1^2 = (X - X_1)^2 + (Y - y_1)^2 + (Z - z_1)^2 + x^2$

$R_2^2 = (X - X_2)^2 + (Y - y_2)^2 + (Z - z_2)^2 + x^2$

$R_3^2 = (X - X_3)^2 + (Y - y_3)^2 + (Z - z_3)^2 + x^2$

$R_4^2 = (X - X_4)^2 + (Y - y_4)^2 + (Z - z_4)^2 + x^2$

where (x_1,y_1) (x_2,y_2) (x_3,y_3) and (x_4, y_4) stand for the location of satellites and R1, R2, R3, R4 are the distances of satellites from the receiver position (Figure-3). Hence solving the four equations for four unknowns X, Y, Z and x, the position or location of the station is calculated.

1. Distance to a satellite is determined by measuring how long a radio signal takes to reach us from that satellite.
2. To make the measurement we assume that both the satellite and our receiver are generating the same pseudo-random codes at exactly the same time.
3. By comparing how late the satellite's pseudo-random code appears compared to our receiver's code, we determine how long it took to reach us.
4. Multiply that travel time by the speed of light and you've got distance.

14. Error in GPS

14.1 Up to now we've been treating the calculations that go into GPS very abstractly, as if the whole thing were happening in a vacuum. But in the real world there are lots of things that can happen to a GPS signal that will make its life less than mathematically perfect. To get the most out of the system, a good GPS receiver needs to take a wide variety of possible errors into account. Here's what they've got to deal with.

14.2 First, one of the basic assumptions we've been using throughout this tutorial is not exactly true. We've been saying that the user calculates distance to a satellite by multiplying a signal's travel time by the speed of light. But the speed of light is only constant in a vacuum.

14.3 As a GPS signal passes through the charged particles of the ionosphere and then through the water vapor in the troposphere it gets slowed down a bit, and this creates the same kind of error as bad clocks. There are a couple of ways to minimize this kind of error. For one thing we can predict what a typical delay might be on a typical day. This is called modeling and it helps but, of course, atmospheric conditions are rarely exactly typical. Another way to get a handle on these atmosphere-induced errors is to compare the relative speeds of two different signals. This "dual frequency" measurement is very sophisticated and is only possible with advanced receivers.

14.4 Trouble with the GPS signal is that it doesn't end when it gets down to the ground. The signal may bounce off various local obstructions before it gets to our receiver. This is called multipath error and is similar to the ghosting you might see on a TV. Good receivers use sophisticated signal rejection techniques to minimize this problem.The whole concept of GPS relies on the idea that a GPS signal flies straight from the satellite to the receiver. Unfortunately, in the real world the signal will also bounce around on just about everything in the local environment and get to the receiver that way too. The result is a barrage of signals arriving at the receiver: first the direct one, then a bunch of delayed reflected ones. This creates a messy signal. If the bounced signals are strong enough they can confuse the receiver and cause erroneous measurements. Sophisticated receivers use a variety of signal processing technique to make sure that they only consider the earliest arriving signals (which are the direct ones).

15. Problems at the Satellite

Even though the satellites are very sophisticated they do account for some tiny errors in the system. The atomic clocks they use are very, very precise but they're not perfect. Minute discrepancies can occur, and these translate into travel time measurement errors. And even though the satellites positions are constantly monitored, they can't be watched every second. So slight position or "ephemeris" errors can sneak in between monitoring times.

16. Ephemeris Errors

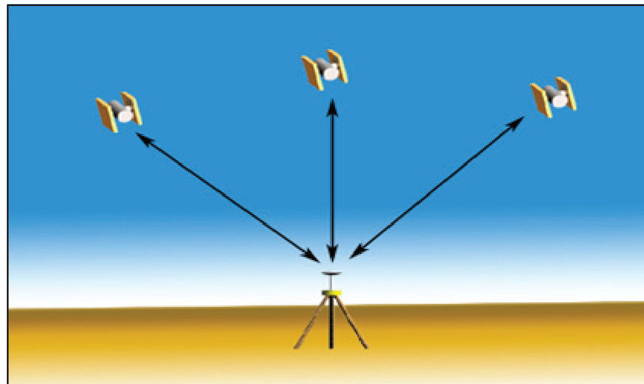
Ephemeris (or orbital) data is constantly being transmitted by the satellites. Receivers maintain an "almanac" of this data for all satellites and they update these almanacs as new data comes in. Typically, ephemeris data is updated hourly.

17. Correcting Errors

1. The earth's ionosphere and atmosphere cause delays in the GPS signal that translate into position errors.
2. Some errors can be factored out using mathematics and modeling.
3. The configuration of the satellites in the sky can magnify other errors.
4. Differential GPS can eliminate almost all error.
   Basic geometry itself can magnify these other errors with a principle called "Geometric Dilution of Precision" or GDOP. It sounds complicated but the principle is quite simple. There are usually more satellites available than a receiver needs to fix a position, so the receiver picks a few and ignores the rest. If it picks satellites that are close together in the sky the intersecting circles that define a position will cross at very shallow angles. That increases the grey area or error margin around a position. If it picks satellites that are widely separated the circles intersect at almost right angles and that minimises the error region. Good receivers determine which satellites will give the lowest GDOP.

18. How is accuracy improved? - Differential GPS

18.1 In order to achieve on-line positioning with high accuracies, Differential GPS (DGPS) is used. Differential positioning uses the point position derived from satellite signals and applies correction to that position. These corrections, difference of determined position and the known position, are generated by a reference receiver, whose position is known and is fed to the instrument, and are used by the second receiver to correct its internally generated position. This is known as Differential GPS (Figure-4). The principal of DGPS is simple. If 2 receivers are placed close to one another, around 100-200 kms they will be subject to the same amount of errors and travel through the same atmospheric conditions. So one uses 2 or more receivers- one at a known point (base) while the other receiver(s) are collecting the data in the field (rover). The base receiver at the known point stores the position data in the memory or on a PC, while the rover stores the data from the field in its onboard or external memory. The computer compares the second by second data from GPS unit at the base with the actual known point data at the base station and determines the amount of error. When the data from the rover is downloaded in the PC, the software applies the corrections to the rover data and corrects the rover readings. This method is called the post processing method. This method, while providing good accuracy has some limitations and disadvantages:



Handheld GPS Positioning, Also know as autonomous or standard positioning

- One needs 2 or more receivers (thereby raising the cost) or access to some base station data from a location within 200 kms from the rover.
- This method also does not provide you with real time navigation capabilities.
- Frequently, if the satellites tracked by the base and rover units are different, the readings will not be corrected.
- The other factor to consider in this method is the fact that for every hour spent in the field to collect the data, one needs to spend about an hour in the office post processing this data .

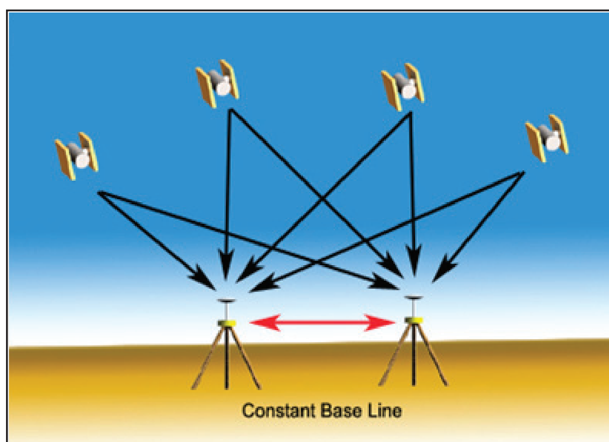


Diagram showing Differential GPS Positioning, also known as relative positioning

18.2 Instead of using the post processing method, one can also utilize the real time correction method. In this case instead of storing the base station data and processing on the PC, the error is calculated in the receiver at the base and broadcast. The U.S. Coast Guard offers one such system and if one has a GPS receiver with an appropriate beacon receiver, one can receive the corrections in real time and accurate GPS readings are displayed. While the service is free, it has a limited range. This range is heavily dependent on the topography of the area. Therefore, this is not a solution for everyone. The second real time system is offered by private companies who are transmitting the correction signals from a satellite. This allows for far better coverage all over the world. But the service ranges around $800.00 to $5,000.00 per year for various areas in the world. Monthly service is also available. The last 2 methods offer the capability of real time accurate readings and therefore good navigation capabilities. Also one does not have to spend time in the office to correct the field data.

19. Uses of GPS

19.1 GPS receivers are used for navigation, positioning, time dissemination, and other research.

- Navigation in three dimensions is the primary function of GPS.
- Precise positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples.
- Time and frequency dissemination, based on the precise clocks on board the SVs and controlled by the monitor stations, is another use for GPS.
- Research projects have used GPS signals to measure atmospheric parameters.
- Georeferencing: that is assigning correct latitude and longitude to the control points of satellite imageries and topographic maps.

19.2 GPS is used in a wide range of activities such as navigation, tracking, positioning, and precision timing, in all sorts of technology sectors. By integrating the navigation, positioning, and timing abilities of GPS with other technologies and data collection, electronic displays, and communications, a vast amount of applications can be created. In forestry there are no shortage of uses. Large game tracking, vehicle dispatch, heavy equipment monitoring, and all sorts of field data collection application have already been initiated.

19.3 GPS has been rapidly evolving over the past few decades. This moving target is sometimes hard to keep up with: dropping prices, new features, Selective Availability (ON then OFF, On and now OFF again), Differential GPS Sources (beacons, satellites, the internet, Bulletin Boards, Wide Area solutions), Dual Frequency, Single Frequency, military bands, civilian bands, code and phase processing. GPS can be used to create and maintain digital map databases for the forests we manage. Field digitizing silviculture features, wildlife habitats, cultural and infrastructure features are partly collected on foot. Fire spotting and areal spraying use GPS in aircraft. Field biologists and sport fishers use “fish finders” with integrated GPS units. Forestry applications that use GPS are continually changing.

19.4 GPS technology offers several advantages: First and foremost, the service is free worldwide and anyone with a receiver can receive the signals and locate a position. Second, the system supports unlimited users simultaneously. Third, one of the great advantages of GPS is the fact that it provides navigation capability.

20. Limitations of GPS

As with any technology, GPS also has some limitations. It is essential that the users are aware of these limitations. One must recognize that a GPS receiver gives a location reading, which is subject to some inherent errors, some under our control and some outside our control. Unless specific steps are taken to improve the accuracy, even with the Selective Availability (SA) of stand-alone receivers can be as much as 15 meters off. In order to obtain a GPS position reading, one needs to occupy the point. Often one cannot get there (maybe you don't want to cross a highway with heavy traffic) or you do not want to get there (wildlife etc.).With GPS, if you cannot occupy a point, you cannot obtain the GPS reading. Even if one can reach the point, the area may be covered with a canopy (thick forest) where GPS signals cannot reach and therefore cannot get the reading. GPS needs clear view of the sky. The elevation readings from GPS receivers are not very accurate. Even with differential GPS, the elevation readings can be 2 to 3 times worse than horizontal readings.

21. Conclusion

The integration of GPS with GIS brings the real world to the desktop. What could take days to visit a specific site and analyze can now be performed on the desktop. The power of GPS/GIS is immense and application are unlimited and varied in all areas such as agriculture, environmental, defense, natural resources, health, business etc. As the price of hardware and software comes down there exists potential of this integration to grow tremendously in country like India. Use of this technology has tremendous application in forestry sector. Use of GIS/GPS & Remote sensing is now being incorporated to prepare the working plan of forest divisions. The tremendous potential of this integrated technology is ever expending.

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Technical Session 4

POOL-WISE DATA REQUIREMENTS AND METHODOLOGIES

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1. Introduction

1.1 The IPCC has categorized the total area of the country into six categories namely; Forest land, Cropland, Grassland, Wetlands, Settlements and Other lands for the reporting of green house gas inventory. To understand carbon dynamics the information of carbon is required for different epoch of time, so that comparison may imply whether the sector is a source or a sink. Thus, the UNFCCC demands information on carbon stored in forest land into two different land classes, one – 'Forest land remaining forest' and second – 'land converted to forest land'.

1.2 In forest ecosystem, enormous carbon is stored which is classified in different five pools by IPCC. The living portion of biomass carbon is classified in two pools: the 'Above ground biomass' and 'Below ground biomass' and are significant store of carbon. The 'dead organic matter' is also classified in two pools: 'Dead wood' and 'Litter'. The fifth pool is 'Soil organic matter' which contains substantial amount of organic carbon.

1.3 It is clear from the above that there are two different kind of information are required one relating to extent of area under forest which is further divided into two groups ie 'Forest land remaining forest' and 'land converted to forest land'. This information is known as 'Activity data'. The other information which is required is poolwise 'Emission factors' which refers to emissions/removals of GHG per unit of area.

1.4 There are number of categories and sub categories for which activity data and emission factors are required and for each of them many options of methodologies are available which need elaboration.

2. General concepts:

2.1 The good practice guidance (GPG) of IPCC uses term "Categories" to refers to specific sources of emissions/removals of greenhouse gases. The 2003 revision of IPCC GPG for Land Use, Land-Use Change and Forestry (LULUCF) or 2006 revision for Agriculture, Forestry and Other Land Use (AFOLU), the categories are: Forest land, Cropland, Grassland, Wetlands, Settlements and Other lands. Each land-use category is further subdivided. The following sub-categories are considered for the sector:

- Forest land remaining Forest land: An increase in the carbon stocks of Forest Land remaining forest land would mean improvement in canopy density and growing stock of forest. A decrease in the carbon stocks of Forest Land remaining

Forest Land is generally considered as degradation of forest resources.

- Forest Land converted to rest of the categories is generally considered as deforestation.
- Land converted to Forest land: Any Non-Forest land converted to Forest land would generally be considered as afforestation.

2.2 According to IPCC GPG, the calculation of greenhouse gas inventories require information on extent (in case of LULUCF, areal) of an emission/removal category termed as **"Activity data"** and emission or removal of GHG per unit of area (removal of CO_2 per ha of added forest area) termed as **"Emission factors"**. The main aim is to estimate these factors for the reporting unit. Once these are estimated then the emission or removal, whatever the case is, can be ascertained using the change in carbon stocks. The carbon stock is measured in metric tons of carbon (generally, metric tons of carbon per hectare, ie, t C ha^{-1}).

2.3 Three different approaches are given in the IPCC GPG to present the activity data (the change in area of different land categories). **Approach 1** identifies the total area for each land category it only provides "net" area. **Approach 2** identifies the land conversions between categories by tracking and provides tabular information about land-use conversion. **Approach 3** involves, in addition, the spatial tracking of land-use conversion. If a country is preparing for REDD mechanism then Approach 3 should be followed since it is likely that only Approach 3 will be acceptable to the concerned authorities responsible for REDD implementation.

Table 1: Approach for activity data

Approach for activity data
1. Total area for each land use category, but no information on conversions (only net changes)
2. Tracking of conversions between land-use categories (only between 2 points in time)
3. Spatially explicit tracking of land-use conversions over time.

2.4 The total carbon which is stocked in the forest is divided into several pools and the emission factors are derived from assessments of the changes in carbon stocks in these carbon pools. These factors are developed using estimates which are used at different levels; global, regional, national and sub-national levels and based on the level-the **Tier levels** are defined which are independent of the Approach being followed. Using these factors, carbon stock information can be obtained at different **Tier levels** (Table 2).

Table 2: Tiers that are used for the emission factors

Tiers for emission factors: change in c stocks
1. IPCC default factors

2.	Country specific data for key factors.
3.	Detailed national inventory of key C stocks, repeated measurements of key stocks through time or modeling.

3. Forest Carbon pools:

3.1 In forest ecosystem, enormous carbon is stored which is classified in five pools by GPG of IPCC. The living portion of biomass carbon is classified in two pools: the 'Above ground biomass' and 'Below ground biomass' and are store significant amount of carbon. The 'dead organic matter' is also classified in two pools: 'Dead wood' and 'Litter'. The fifth pool is 'Soil organic matter' which contains substantial amount of organic carbon.

Table 3 Different forest carbon pools

Pools		Description
Living Biomass	Above ground biomass	All living biomass above the soil including stem, stump, branches, bark, seeds and foliage. Note: In cases where forest under-storey is a relatively small component of the above ground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series.
	Below ground biomass	All living biomass of live roots. Fine roots of less than 2mm diameter (country specific) are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Dead Organic Matter	Dead wood	Includes all non living woody biomass not contained in the litter, either standing, lying on the ground. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10cm in diameter or any other diameter used buy the country.
	Litter	Includes all non-living biomass with a diameter less than a minimum diameter chosen by the country (for example 10 cm), lying dead, in various states of decomposition above the mineral or organic soil.
Soil	Soil organic matter	Includes organic carbon in mineral and organic soils (including peat) to a specific depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included with soil organic matter where they cannot be distinguished from it.

Note: National circumstances may necessitate slight modifications to the pool definitions used here. Where modified definitions are used, it is good practice to report upon them clearly, to ensure that modified definitions are used consistently over time, and to demonstrate that pools are neither omitted nor double counted.

4. Methodologies for Assessing 'Activity data'

4.1 Three different methodologies are available and being used by different countries to assess the extent of area under 'Forest land remaining forest' and 'Non-forest land converted to forest'. These methodologies are

1. Wall-to-wall mapping using remote sensing data,
2. Mapping of sampled areas using remote sensing data and
3. Using field survey methods.

4.2 If Remote sensing data is decided to be used, then it is recommended to use IRS LISS III-type remote sensing data (23.5m spatial resolution) for monitoring forest cover changes with 1 ha Minimum Mapping Unit (MMU). These data will enable the assessment of changes of forest area and producing a map of forest area using a common forest definition. A hybrid approach combining automated digital classification techniques with visual interpretation may be used. This technique is generally used as it is simple, robust and cost effective.

4.3 NASA has provided the only free global mid-resolution (30m) remote sensing imageries (Land sat satellite) for around years 1990, 2000, and 2005 with some quality issues in some parts of the tropics (clouds, seasonality, etc.) which can be utilized by any user agency.

4.4 The specifications on minimum requirements for image interpretation are:

1. Geo-location accuracy <1 pixel, i.e. <30m,
2. Minimum mapping unit should be between 1 and 6 ha,
3. A consistency assessment should be carried out.

4.5 For the national forest cover and forest cover change assessment, generally, following steps are necessary :

1. Selection of the approach:
    a. Assessment of national circumstances, particularly existing definitions and data sources
    b. Definitions of change assessment approach by deciding on.
        i. Satellite imagery
        ii. Sampling versus wall to wall coverage
        iii. Fully visual versus semi-automated interpretation
        iv. Accuracy or consistency assessment
    c. Plan and budget monitoring exercise including:
        i. Hard and software resources
        ii. Requested Training
2. Implementation of the monitoring system:
    a. Selection of the forest definition
    b. Designation of forest area for acquiring satellite data
    c. Selection and acquisition of the satellite data
    d. Analysis of the satellite data (preprocessing and interpretation)
    e. Assessment of the accuracy

5. Estimation of Emission factors

5.1 Definitions:

It is important to define the forest prior to estimation procedure. The definition of forest for the country may be different from the other countries or being followed by international organizations like FAO etc. One should choose a definition which can serve the national objectives and with slight modification in information international commitments may also be fulfilled. For example:

FAO's definitions

Tree: A woody perennial with a single main stem, or in the case of coppice with several stems, having a more or less definite crown. Includes: bamboos, palms and other plants meeting the above criterion.

Forest: Land with tree crown cover (or equivalent stocking level) of more than 10 percent and area of more than 0.5 hectares (ha). The trees should be able to reach a minimum height of 5 m at maturity in situ. Includes: forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, Excludes: Land predominantly used for agricultural practices (Kleinn, 1991).

Forest Survey of India's definitions:

Tree: A woody perennial with a single main stem, having 10 cms or more diameter at breast height (1.37m). If there are several stems then those which has attained 10 cms dbh will be considered as individual trees.

Includes: bamboos, palms and other plants meeting the above criterion.

Forest Cover: All lands with a tree canopy density of more than 10 per cent and area of more than 1.0 ha.

5.2 Tier wise data requirement:

The data has to be generated according to definitions and the targeted tier level for example Tier1 does not require any new data collection but to consider the IPCC tables for default values. Whereas for Tier3, lot of resources are required for the countries where national forest inventory (NFI) is not being conducted (i.e. most developing countries).

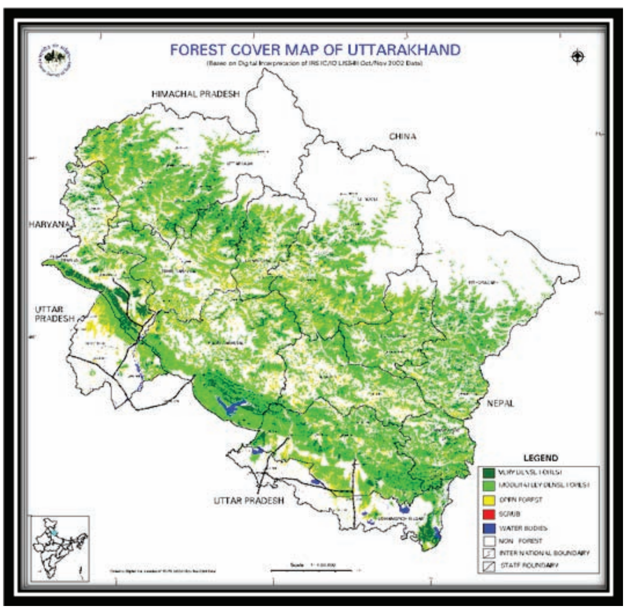
Table 4 Data requirements of the three IPCC tiers

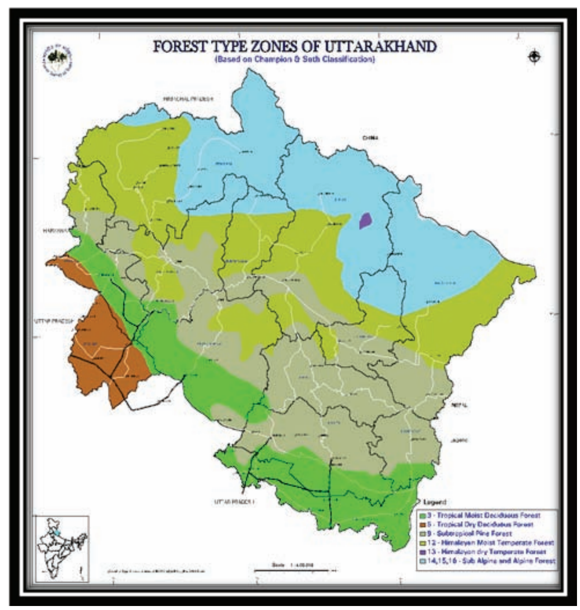
Tier	Data needs/examples of appropriate biomass data
Tier 1 (basic)	Default MAI (for degradation) and/or forest biomass stock (for deforestation) values for **broad continental forest types**- includes six classes for each continental area to encompass differences in elevation and general climatic zones; default values given for all vegetation-based pools
Tier 2 (interme-diate)	MAI and/or forest biomass values from **existing forest inventories** and/or **ecological studies**. Default values provided for all non tree pools Newly-collected forest biomass data.

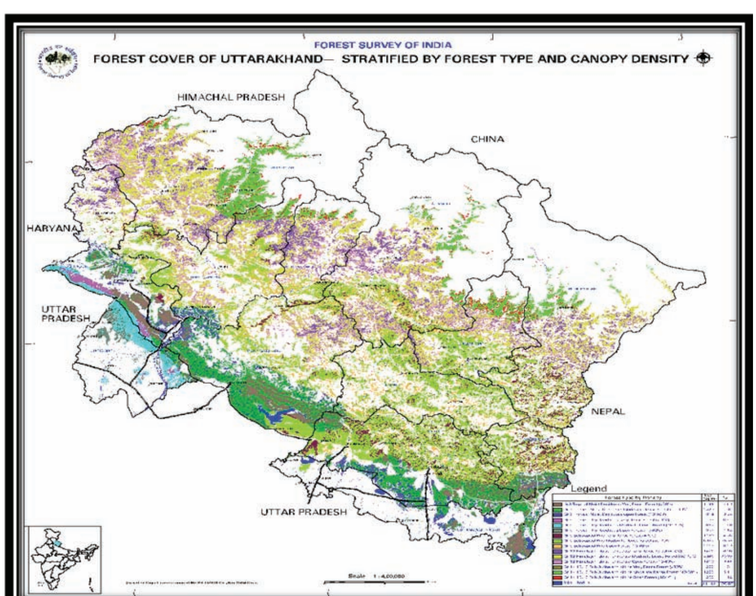
Tier 3 (most demanding)	**Repeated measurement of trees** from permanent plots and/or calibrated process models. Can use default data for other pools **stratified by in-county regions and forest type**, or estimates from process module.

5.3 Stratification of Forest area:

Stratification is required for any heterogeneous population to gain precision of estimates by dividing it into relatively homogeneous sub-population based on some stratification variable. Since, in this case, carbon stored in the vegetation is principal variable which definitely depends upon canopy density and forest type; these two may be considered as stratification variables. For example, forest of Uttarakhand state of India is stratified using these two stratification variables as shown below:







If there are five forest types and three canopy classes then there will be fifteen strata of forest, and for each of them emission factors will be required for each carbon pool.

5.4 Carbon pools to be considered:

There are many considerations before proceeding for estimation of emission factors. These considerations are based on administrative, financial, technical expertise, practical aspects like:

1. The principle of conservativeness
2. Financial resources
3. Availability of existing data
4. Ease of measurement
5. The magnitude of potential change in the pool

The principle of conservativeness implies that the decrease in emissions is not overstated. The estimates of the two periods should be for the same pool and should be arrived at following same or similar methodology.

5.5 Carbon measurement pools:

5.5.1 Aboveground tree biomass:

This pool is one of the most important and should be part of the assessment as the carbon stock of this pool contribute maximum to carbon stock changes and is simple to measure and estimate. Part of this biomass is by default, measured if any forest inventory has been conducted. Generally, biomass of small wood, foliage and bark are not captured when volume equations are being used in the forest inventory. All small trees which do not qualify the threshold of dbh, kept for inventory also are not accounted for. Similarly, shrubs, herbs, grasses and climbers are also not included. For including such biomass in calculation, volume expansion factor (VEF) and biomass conversion and expansion factor (BCEF) are used.

5.5.2 Belowground tree biomass:

This is one of the most difficult part to measure and generally belowground tree biomass (roots) is not measured in inventory, but being included through a relationship (usually a root-to-shoot ratio) to aboveground biomass which have been established by various researchers.

5.5.3 Dead wood:

Dead wood stocks are usually assessed along a transect or by laying optimum number of sample plots in all the sub-population, with the simultaneous collection of data on weight and subsequent drying of samples for density. Then strata wise (sub-population) per unit of area biomass is assessed and converted to carbon stock.

5.5.4 Litter:

Litter generally forms a part of forest inventory and is collected. If it is not, then the similar methodology that of dead wood is to be used.

5.5.5 Soil organic matter:

In many countries this component has become integral part of inventory and samples are collected from all the sample points and analysed in laboratory for percent of soil carbon. If it is not a part of inventory then optimum number of samples of soil are collected from each strata and then must be analysed in a laboratory for bulk density and percent soil carbon.

6. Methodology of current estimation of forest carbon stock by FSI:

6.1 The current methodology aims to completeness of the data and improvement of the accuracy level to follow Tier 2 approach of IPCC good practice guidance for LULUCF using country specific data. For this purpose FSI under took a special nation wide study since August 2008 on missing components of forest biomass for generating country specific information.

6.2 The input used in the methodology is;

i) Latest forest cover (of years 2005) and forest type area data analyzed by remote sensing
ii) Recent growing stock data obtained from National Forest Inventory done during 2002-2008
iii) Soil organic carbon data obtained from NFI
iv) Biomass data of missing components (smallwood, branchwood, deadwood, litter, shrub, herb and foliage) analyzed from 2008-09 study.
v) IPCC default values for below ground biomass

6.3 Most of the input used for estimating the forest carbon stock has been generated at the FSI. The specific gravity for determining the biomass and factors for converting biomass into carbon has however, been taken from published papers from FRI and other research institutes in addition to IPCC default values.

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Technical Session 5

FOREST COVER ASSESSMENT

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1. Introduction

1.1 Realistic assessment of the forest cover at landscape level is a challenge to which the scientists and forestry Geomatics experts are trying to address. In this endeavour a substantial success has been achieved with the result that today the forest cover mapping is done using the latest technological interventions in the fields of remote sensing, GIS and ground observations.

1.2 The forest is a complex ecosystem consisting mainly of trees that form a buffer for the earth to protect life forms. The trees which make up the main area of the forest creates a special environment which, in turn, affects the kinds of animals and plants that can exist in the forest. These plant communities cover approximately 9.4% of the Earth's surface (or 30% of total land area), though they once covered much more (about 50% of total land area), in many different regions and function as habitats for organisms, hydrologic flow modulators, and soil conservers, constituting one of the most important aspects of the Earth's biosphere.

1.3 The world's forests provide vital economic, social and environmental benefits. They supply wood and non-wood forest products, support human livelihoods, supply clean water and provide habitat for half the species on the planet. International processes related to forests demand accurate information on tree cover and forest resources. For the objective Forest Resources Assessment, a systematic, comprehensive, global survey of forests based on remote sensing imagery is being undertaken worldwide.

1.4 The Remote Sensing Survey (RSS) helps to improve *inter alia* understanding of total forest area changed, the patterns resulting from this change, and the processes driving forest cover change globally. This is the kind of information which governments, land managers, researchers and civil society groups can use to make better-informed decisions regarding the world's forest resources.

2. The need for accurate and timely information on forest area

2.1 Forests and forest management are coming under increasing scrutiny as agents of climate change mitigation, most notably through the Reducing Emissions from Deforestation and Degradation (REDD) initiatives (since Bali, 2007). During a 2008 G-8 Summit, world leaders *"encouraged actions for REDD including the development of an international forest monitoring network building on existing initiatives".* With this background the need for an objective and verifiable forest cover assessment is all the more pronounced.

2.2 Forest cover dynamics change on local to regional scales but contribute to local, regional, and global impacts on climate, biodiversity and ecosystem services. The Clean Development Mechanism under the United Nations Framework Convention on Climate Change (UNFCCC) and REDD are two of the initiatives being developed to help reduce the negative effects of forest loss on climate but issues of accounting for and monitoring forest resources remain difficult to resolve.

2.3 Historically, the quantity and quality of data available for reporting the extent of forest cover varies widely on a country-by-country basis. Forest definitions change from place to place based on national definitions, cultural values and the purpose of the assessment and the methodology used. Many countries also lack consistent, historical records and technical or financial capacity to adequately report on changes in forest area over time. FAO, through the Forest Resources Assessment (FRA) process, is working to strengthen national technical capacity thereby improving forestry-related information gathering and reporting.

3. Why remote sensing?

3.1 Satellite remote sensing offers the advantage of broad area coverage, systematic observations, and the ability to use standardized, repeatable analyses to characterize the Earth's surface. It is one of the only comprehensive sources of information available for many of the large, forested areas on Earth. Though remote sensing does not replace the need for field-collected data, it offers distinct benefits when conducting large-area surveys for broad vegetation-type categories.

3.2 The remotely sensed imagery and classification process of the RSS will more adequately describe both physical tree cover and the variably defined 'forest area'. Accurate and timely information at regular interval on the distribution of natural resources on earth is of top priority for understanding dynamics of the human induced land cover/land use accelerated changes. This information can be further utilized in understanding biophysical processes of the earth. In India and the other developing countries it is mostly been lost for the agricultural practices. Aerospace technology is a potential means of collecting information about natural resources including forests at any desired time. The technology is considered important to revise or update available information. Satellite remote sensing has played a pivotal role in generating information about forest cover, vegetation type and land use changes (Roy 1993).

3.3 The present paper addresses the basic issues involved in the forest cover assessment and methodology of the same being carried our in India and at the Forest Survey of India. It discusses the potential of remote sensing technology for managing forests in general and sustaining the pace of development in this technology. It focuses the technology trends and techniques for tropical forest assessment at different scale and levels. For sustained yield from forest, it is essential to manage them scientifically which would require up-to-date statistics of their extent type etc. (Mayers 1991, 1992). The SPOT Panchromatic image (10 m on each side); IRS 1C/1D PAN data (5.8 m) and Space Imaging, Cartosat, OrbImage offer greatly enchanced spatial resolution of 1 m panchromatic and 4 m multispectral pixels and Quckbird MX pixels of 2.4 m spatial resolution are as good as aerial photographs. Satellite imagery with high spatial resolution gives forests a new set of mapping and monitoring options. (Roy 2002)

4. Forest Cover Assessment

History of Forest Cover Mapping by the FSI

4.1 The Forest Survey of India (FSI) is a premier national forest resources survey organization in the country under the Ministry of Environment and Forests, Government of India. As a successor to Pre-investment Survey of Forest Resources (PISFR), it was created and effected from June 1, 1981. Its primary mandate is to furnish data through countrywide comprehensive forest resources survey at regular intervals. In India the National Remote Sensing Agency, Hyderabad (Department of Space) in 1982 demonstrated the use of satellite data in mapping forest cover of the country.

4.2 Concomitantly, the Forest Survey of India (FSI), an organization under the Ministry of Environment and Forests, Government of India, also developed the capacity to interpret and classify the satellite data for assessment and mapping of forest cover. FSI used Landsat (MSS) imagery during the period 1981- 83 for the first assessment of forest cover. The technique used for interpretation of satellite data was visual interpretation and scale of interpretation was 1:1 million. Interpretation was followed by extensive ground truthing. The forests were classified into dense forest (crown cover of more than 40%) and open forests (crown cover between 10-40%). Mangroves were delineated as a separate class. Degraded forests having crown cover of less than 10% were classified as scrub (a nonforest category).

4.3 The FSI switched over to digital interpretation of satellite data commencing from the year 2001. Before that it was using mostly visual interpretation of satellite data on 1:250,000 scale for assessment of forest cover. It used digital interpretation of satellite data on 1:50,000 scale for mapping and monitoring forest cover. As per the latest assessment forest cover of the country was estimated in SFR 2009 to be 69.09 million Ha. (21.02% of country's geographic area).

4.4 The Current methodology uses Digital Image Processing software and involves the following steps (Rawat *et al.* 2003):
Acquisition of satellite data: The digital data of Resourcesat-1 is acquired from NRSA in CD. India is covered in about 340 scenes. One scene covers an area of about 20000 km^2, having an overlap of about 10% with adjoining scenes. While procuring the data, care is taken to ensure that it is cloud free (with not more than 10% cloud cover) and therefore data pertaining to the period from October-December is preferred.

4.5 Geometric Rectification of raw data: After downloading the data into computer, rectification is carried out in each image to provide Latitude and Longitude information into raw satellite scene using raster based geometric corrections. Rectification carried out in geographic projection is re-projected in the shape of polygonal projection and the scene is geo-coded by using SOI toposheets.

4.6 Mosaicing of rectified scenes: Different scenes, which are already rectified, may have to be merged together to get one combined FCC (False Colour Composite). FCC of sheet is extracted from mosaiced scene in a chosen area of interest. Image is displayed in three bands 3, 2, 1. Masking of non-forest areas is done separately to extract forest areas on the basis of ground knowledge, cover map of previous cycles and on the basis of information available through SOI toposheets in the area of interest.

4.7 Classification of forest cover using NDVI: Interactive method of display is used for assigning threshold values for each class (open, dense and scrub) on the basis of the ground knowledge to highlight forest/vegetated areas. Density class of forest cover and colour is accordingly allocated. Survey of India toposheets is used for delineating boundaries of each district and classified map of forest cover is generated.

4.7 Flow chart of methodology of dynamic forest cover mapping using remote sensing is shown in the Fig.1.

Flow Chart : Forest Cover Mapping

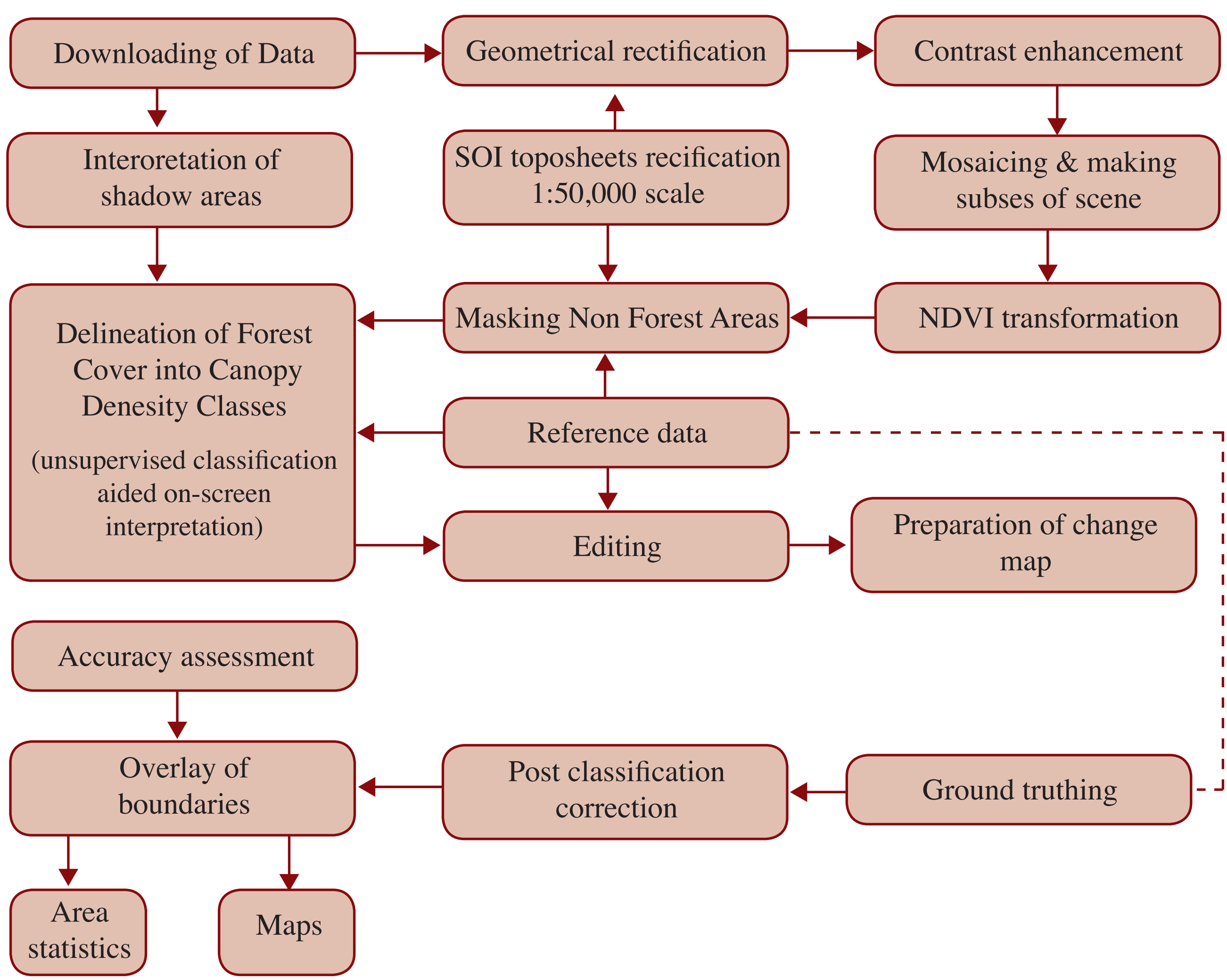

Fig.-1 Source. FSI

4.8 The output includes forest cover maps on 1:50,000 scale. These maps show forest cover in four classes-

(i) Very Dense forest, having canopy density of more than 70%,
(ii) Moderately dense Forests with canopy density 40%-70%.
(iii) Open Forests with canopy density between 10-40% and
(iv) Scrub which are forest areas having less than 10% canopy density.

These maps are also generated for district and States/Union Territories by overlaying the respective District/State/UT administrative boundary. Area under forest cover at District/ State/country level is then assessed. Change maps are also prepared to depict changes taking place under different land cover classes.

4.9 In its assessment of 2009, taking advantage of advancements in remote sensing and improvement in digital interpretation qualities, FSI has provided a much more comprehensive status of forest cover in the country than in the previous assessments. Some of the new features incorporated in this assessment are:

- For the first time FSI has interpreted the satellite data of the entire country digitally. In earlier estimates, interpretation has been largely visual. Digital interpretation has the advantage of overcoming subjectivity prevalent in visual method.

- Due to absorption of digital image processing technique, it has been possible for FSI to interpret the data on 1:50,000 scale. This has resulted in providing more realistic information on forest cover as areas having forest cover down to 1 ha could be delineated while in earlier assessments, forest cover down to 25 ha could only be delineated. Similarly blanks down to 1 ha within forested areas can be separated. The entire exercise has resulted in new base-line information on forest cover.

- As perennial woody vegetation (including bamboos, palms, coconut, apple, mango etc.) has been treated as tree and thus all lands with tree crops, such as agro-forestry plantations, fruit orchards, tea and coffee estates with trees etc., have been included in forest cover.

- Mangrove cover has been classified into dense and open mangrove cover. The area of mangrove cover so assessed has been merged in the respective area figures of dense and open forest cover.

- A classification is not complete unless its accuracy is assessed. For the first time an independent and systematic assessment of accuracy of satellite data interpretation was made. **An error matrix was generated by comparing classified forest cover with the actual forest cover on the ground at 4302 locations spread throughout the country. High resolution Multispectral data was used as proxy for ground verification. The overall accuracy of forest cover classification was found to be 95.72%.**

- Though forest cover in areas as less as 1 ha in extent could be assessed using satellite data, significant tree cover exists in patches of less than 1 ha and in linear shapes along roads, canals, etc. and scattered trees that can not be assessed using remote sensing. An attempt is made for the first time to assess such tree cover using ground inventory method.

Forest Cover Assessments by FSI

A Brief History

Cycle	Year of Assessment	Setellite & Sensor	Resolution	Scale
I	1987	LANDSAT MSS	800m X 80m	1:1 million
II	1989			
III	1991	LANDSAT TM	30m X 30m	
IV	1993			1: 250,000
V	1995			
VI	1997	IRS-IB LISS- II	36m X 36m	
VII	1999	IRS-IC LISS- III	23m X 23m	
VIII	2001	IRS-IC/ID LISS- III	23m x 23m	1: 50,000
IX	2003	IRS-ID LISS- III	23m x 23m	1: 50,000
X	2005	IRS-P6 LISS- III	23m x 23m	1: 50,000

Fig.-2 Source. FSI

4.10 The increase in processing speed and the compression techniques for digital storage have made digital imaging available to anyone. One advantage of digital imagery for natural resource managers is that it can be enhanced on the computer to bring out details of interest – whether vegetation stress, species composition, or growth and volume. The standardization of ground sampling methods, understanding of spectral and temporal responses of vegetation have brought acceptance of the application of satellite remote sensing data in forest inventory and mapping (Roy & Joshi 2000a, 2000b).

5. Screen digitization – heads on

5.1 It is most recent technique used commonly at present. In this method the digital multi-spectral images are visualized on-screen for thematic interpretation purpose and direct delineation of the theme on the screen. The scale selected for interpretation is corresponding to minimum mapping units and with diameter reaches to linear features.

During screen digitization, first the linear features are delineated followed by boundary of group/class and then interspersed features. Unlike visual image interpretation it facilitates the analyst to use different band combination for visual interpretation on screen (Roy & Murthy 1984).

6. Digital classification

6.1 In the digital classification technique all the pixels in image are categorized into land cover classes or themes. It is conducted in two different modes. Supervised classification, in which the analyst ‘supervises’ the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various land cover type present in a scene. The different algorithms used for supervised classification are minimum-distance-to mean, parallelepiped, and Gaussian maximum likelihood classifier (Roy *et al.* 1982). In the Unsupervised approach, the image data are first classified by aggregating them into the natural spectral grouping or clusters, present in the scene. The different algorithms commonly used for unsupervised classification are ‘K-means’, ISODATA clustering and texture/roughness based classification. Hybrid classification involve aspects of supervised or unsupervised or both and is aimed to improving the accuracy or efficiency of the classification process. Guided clustering is a hybrid approach that has shown quite effective results in some natural circumstances. Hierarchical classification technique is something in between supervised and unsupervised classification aimed to get best land use/land cover map with maximum accuracy.

7. Initiative on global forest cover Assessment

7.1 Processing optical data, Segmentation and Classification, Labeling and Legend (FAO approach)

7.1.1 The Landsat satellite imagery of the different sites needs to be first radiometrically corrected and harmonized. The imagery has been processed to high level enhanced and normalized products. Normalization and enhancement reduce atmospheric interference and improve the interpretability of the imagery. Additional imagery inputs for each chip include a cloud mask, water mask, and data/no data mask.

7.1.2 The RSS uses a multi-date, multi-resolution image segmentation approach for classifying each survey tile. Normalized Landsat bands 3, 4, and 5 from the GLS1990, 2000, and 2005 datasets are used for producing segmented images on the sample sites. Image segmentation is performed using mainly the commercially available software e-Cognition. The results are polygon layers containing information from different time periods of imagery. The polygon layers are classified separately for each time period using Landsat optical bands (1-5 and 7), resulting in three land cover maps for the 1990s, 2000s, and 2005s. Changes in land cover over time are captured in the polygons and reflected in changes in land cover labels assigned during the classification process. Several tuning parameters can be adjusted to optimize segmentation results and in the case of the RSS, they are adjusted on an image by image basis such that the resulting minimum mapping unit is approximately 5 hectares. Producing the final land cover polygons is a two-step process. The first step is a draft pre-labeling exercise followed by label correction and validation by in-country experts. Polygons are classified and pre-labeled in one of two ways: (i) automatically using spectral training signatures and (ii) by visual interpretation.

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Technical Session 6

FOREST TYPE MAPPING

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1. Introduction

1.1 India is endowed with a vast range of edaphic, climatic and physiographic conditions. Diverse conditions of plant growth in the country have resulted in vast diversity of flora and fauna in the country. India figures in the 12 mega biodiversity regions of the world. Forests in the country vary from evergreen tropical rain forests in the Andaman & Nicobar Islands, the Western Ghats and the north-eastern States, to dry alpine scrub high in the Himalayan region. Between the two extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, sub tropical pine forests in the lower mountain zone and temperate montane forests (Lal, 1989). It is important to understand the interrelationship between the natural vegetation and the environment in which it exists to manage and conserve the forest resources. Any intervention for development and conservation of forests requires a careful understanding of the eco-system as a whole. Classification of forests into different types based on physiognomy, structure and floristics vis-à-vis the physical environment is primarily meant to meet this requirement.

1.2 Forest type is defined as ‘a unit of vegetation which possesses (broad) characteristics in physiognomy and structure sufficiently pronounced to permit its differentiation from other such units. This is irrespective of physiographic, edaphic or biotic factors’ (Champion & Seth, 1968).

1.3 The forest type is the foremost information required to carry out any scientific study on forests or to take a rational decision for their management. Description of forests of any area into the forest types provides a scientific basis for the analysis in diverse applications such as management, silvicultural research, resource assessment, environment impact assessment, wildlife management etc.

2. The Project: Forest Type Mapping of India

2.1 The project on forest type mapping of India was initiated by the Forest Survey of India in March 2005 under the National Natural Resources Management System (NNRMS) of the Ministry of Environment and Forests of Govt. of India. The main objective of the project was to map the forest types of the country following Champion & Seth Classification (1968).

2.2 Under the project, forest type mapping of all the districts of the country has been done on 1: 50,000 scale. The final output of the project is available in the form of this report and a national atlas showing forest types of the States and UTs. The forest type maps of every part of the country will also be available in the digital and hard copy forms. The methodology for the project was evolved on the basis of the pilot studies carried out in three selected districts located in different parts of the country, the in-house R&D carried out at FSI, and the expert consultations held from time to time in which participants from the States & UTs Forest Departments (SFDs) and various central govt. agencies eg. Survey of India, NRSC, and SAC contributed. The State Forest Departments were actively involved in the project from the methodology development stage to ground verification, feedback on the provisional maps and accuracy checking.

3. Objectives

Objectives of the project were as follows:

1. Preparation of a detailed report on forest type mapping of the country (using the classification scheme by Champion and Seth, 1968).
2. Generation of forest type maps for the entire country at 1:50,000 scale and on a larger scale for some important areas.
3. Publication of an atlas depicting the forest type maps for different regions, States/UTs of India.

4. Significance of Forest Types

4.1 Right from the inception of the first National Forest Policy of 1952, there has been a high degree of emphasis on the conservation of natural forests in the country. Recognizing the significant ecological functions of the forests, the National Forest Policy (1988) aims at maintaining one-third of India's land area under forest and tree cover. Scientific information on the forest resources like extent and distribution of forest types of the country is prerequisite to the implementation of policy and planning for conservation of forests.

4.2 The panorama of Indian forests ranges from Evergreen Tropical Rain Forests in the Andaman and Nicobar Islands, the Western Ghats, and the northeastern States, to Dry Alpine Scrub high in the Himalayas in the north. The country has Semi-Evergreen Rain Forests, Deciduous Monsoon Forests, Thorn Forests, and Subtropical Pine Forests in the lower montane zone and Temperate Montane Forests in the higher ones. The Andaman and Nicobar islands have Tropical Evergreen Rainforests and Tropical Semi-Evergreen Rainforests.

4.3 Each forest type is unique in terms of dominant species, species association, physiognomy and structure. Because of the uniqueness of the forest types, the silvicultural treatment required to manage each type would in principal be specific. Similarly, the ecological functions, biodiversity, socio-economic interaction of each forest type would be different from each other. Identification of different forest types therefore is very important from the considerations of policy, management, valuation, conservation priority and assessment. In Indian context, the important applications which highlight significance of forest types are mentioned as follows:

- signifies natural floral biodiversity
- an appropriate basis for stratification of forests
- important input in management and Working Plans
- basis for determining qualitative change in the forests with time
- facilitates valuation of forests – NPV
- characterizes forests in productivity value
- basis for carbon assessment – (could be an important input in REDD methodologies)
- application in climate change studies
- an important consideration in impact studies
- useful information in various forest related studies

5. Definition of Forest Type

Forest type may be defined as "*a unit of vegetation which possesses (broad) characteristics in physiognomy and structure sufficiently pronounced to permit of its differentiation from other such units* "(*Champion & Seth, 1968*).

5.1 Forest type has got a bearing on silvicultural and management practices. In a given location it mainly depends on the climate, the soil and the past treatment. Climatic factors include temperature, rainfall and wind. Topographical features like altitude, slope and aspect are also important as they influence local climate and soil.

6. Classification by Champion & Seth (1968)

6.1 The revised forest type classification by Champion and Seth (1968) is the most widely used classification system for the forest types of India. This classification is basically a revision of the forest type classification earlier given by Champion for the whole of the Indian sub continent in 1935. The other notable forest type classification systems for Indian sub continent are of Beard (1944), Fosberg (1958), Webb (1959), Burtt-Davy (1938), Swain (1938), Kuchler (1949) and Puri (1960).

6.2 The type of natural vegetation in a given locality depends on the climate, soil, topography and the past treatment. The climatic factors include temperature, rainfall and wind. The topographical features like altitude, slope and aspect are important because of their influence on local climate and soil.

6.3 Champion and Seth classified forests of India into six major groups based on climate conditions. These major groups have been further divided into 16 type groups based on temperature and moisture contents. These type groups have been further divided into southern and northern forms. Ultimately the type groups have been classified into 200 forest types and subtypes including variations based on location specific climate factors and vegetation formation.

6.4 The above classification scheme of Champion & Seth (1968) gives an elaborate description of each forest type based on minute and exhaustive observations of the authors during their extensive tours to the vast forest areas of the country. Using the maps available at that point of time, the authors have described the spread and distribution of most of the above forest types. It was practically not possible to produce a cartographic map of forest types of India at that point of time. The authors however gave a diagrammatic map which broadly gives regions of 16 type groups of forests. It indicates likely forest type group of natural forest occurring in a particular zone. The map given in the book in A4 size has been reproduced below (Fig 2.4). With the advancement in technology, particularly with the advent of spatial technologies like remote sensing and GIS now it is possible to map the forests into different types as described in the classification given by Champion and Seth (1968) taking spatial layers of different factors into account. This project is the first effort for the wall-to-wall mapping of forest types of India following Champion & Seth Classification system.

7. Factors Responsible for Forest Types

Forest is a complex ecosystem consisting of trees and other vegetation forms that shield the earth and support innumerable life forms. Forests can develop wherever there is an average temperature greater than about 10°C in the warmest month and an annual rainfall in excess of about 200 mm annually, except where natural fire frequency is too high, or where the environment has been impaired by natural processes or by human activities.

Forests are classified according to their nature and composition, the type of climate in which they thrive, and their relationship with the surrounding environment. The main factors that are considered to be responsible for development of different forest types in Champion and Seth's System of classification are as follows

7.1 Climate

i) **Temperature** – It is the most obvious factor of climate. It can be broadly related to latitude giving a rough differentiation into four zones: a) Tropical b) Subtropical c) Temperate and d) Arctic (*Champion & Seth, 1968*). Latitude and altitude define the temperature condition. On the basis of temperature India may be divided broadly as follows:

	Zone	Mean Annual Temperature	Mean January Temperature	Winter
I	Tropical	Over 24°C	Over 18°C	None: no frost
II	Subtropical	17° to 24°C	10° to 18°C	Definite but not severe: frost rare
III	Temperate	7° to 17°	-1°to 10°C	Pronounced with frost and some snow
IV	Alpine	Under 7°C	Under -1°C	Severe, with much snow

Temperature decreases with increasing altitude by a normal lapse rate of 3.3 degrees Centigrade for each 1000m of altitude.

ii) **Rainfall –** As regards total annual rainfall, India exhibits an extremely wide range of conditions from less than 150mm in the Thar desert to nearly 5,000mm locally in the Khasi hills of Meghalaya. Precipitation over 2,500mm is met with in three different parts of the country viz Western Ghats; North Bengal, Assam & Meghalaya, and locally in the Western Himalayas at Dharamshala (H.P). The annual rainfall increases with increasing elevation in the first instance. It depends on the situation of the place whether on the windward or leeward side of high ridges. The interior ranges receive markedly lower rainfall than the frontal ranges for a given elevation. With further increase in elevation, rainfall tends to decrease. At higher altitude snowfall becomes the substantial contributor to the total precipitation.

7.2 Soil

The physical conditions of the soil, moisture content, root aeration and availability of chemical nutrients, are much more influential on species and forest type distribution. There are many species with the type they dominate which depend on the soil type e.g., *Cupressus torulosa* generally restricted on the limestone formations.

7.3 Altitude

Altitude also plays an important role in determining the type of forest. As already mentioned variation in temperature and rainfall are the direct effects of altitudinal variation.

7.4 Topography

In the flat regions, factors most affecting the vegetation is the minor difference of levels determining the movement of water both over and through the soil. In hilly areas the factors of topography that exert most influence on vegetation are aspect and gradient.

7.5 Past Management

Management of forest in the past also has bearing on forest type due to altered micro climatic conditions, silvicultural operations, felling of trees etc. Sustained management prescriptions over a period of time influence the ecological succession process as well. This leads to evolution of a forest type different than the forest type in natural conditions without any intervention.

7.6 Socio-economic Conditions

Whether in the hills or the plains, there is very little forest in India that can be accepted as having always been free from biotic influences. Fire and grazing have played an extremely influential role in determining the forest type. Shifting cultivation has been a deciding factor especially in the North Eastern part of the country. Once the area has been clear felled, the chances of original vegetation coming up properly are poor.

8. Ecological Perspective of Forest Types

8.1 Communities can be described as assembly of species that coexist in an area at certain times and interact with one another. But communities are more than the sum of the species; they also represent the myriad of biological and environmental interactions that are inherently a part of each unique natural system. Clements's (1916) theory on plant succession explains development of plant communities. Succession is a directional non-seasonal cumulative change in the types of plant species that occupy a given area through time. It involves the processes of colonization, establishment, and extinction which act on the participating plant species. Most successions contain a number of stages that can be recognized by the collection of species that dominate at that point in the succession. Succession begins when an area is made partially or completely devoid of vegetation because of a disturbance. Some common mechanisms of disturbance are fires, wind storms, volcanic eruptions, logging, climate change, severe flooding, disease, and pest infestation. Succession stops when a community attains climax which is marked by minimum or no change in the species composition of the plant community. The theory assumes that all plant communities will in time develop progressively towards a form which is in equilibrium with the prevailing climate and will then be stabilized as climatic climax. The soil also influences and gets influenced by climate and vegetation and reaches a stable climax. If the vegetation has been disturbed in any way, a secondary succession will set in similar to the primary succession but in a different manner. The concept of climax patterns is implicit in the definition of a forest type as an average population with distinct broad physiognomic and structural characteristics. Floristic composition which leads to structure and appearance of a forest type, depend on the local flora, ie the number and character of the species.

The ecological community concept has been recognized as an important conservation planning tool for the following reasons:

- Ecological communities have inherent values worth conserving. They encompass a unique set of interactions among species and contribute to important ecosystem functions.
- Communities can be used as surrogates for species and for ecological processes, particularly in species-rich and data-poor areas such as the tropical areas.
- Monitoring change over time is often most meaningful when done at the level of communities. Changes may be detected in overall species abundance, including the proportion of non-native species; in structure, such as the development of old-growth characteristics; and in function, such as alterations in nutrient cycling.
- Communities are an important tool for systematically characterizing the current pattern and condition of ecosystems.

9. Methodology

9.1 Forest Survey of India carries out mapping of forest cover biennially using remote sensing data. The forest cover includes tree patches of extent 1 ha or more of the natural forests and the trees outside forests. Forest cover layer prepared by FSI has been taken as base map giving forest cover distribution for this project. In short, the exercise of forest type mapping aims at assigning forest types to the forest cover. Patches of natural forest cover or the old forest plantations which have naturalized over a period of time have been assigned forest types under this exercise. Scrub class shown in the forest cover map which represents natural degraded forest land has also been taken into account for the purpose of forest type mapping, though scrub is not included in the forest cover given in the SFR. The final output of this exercise i.e. forest type map would therefore overlap with the forest cover map including scrub (VDF, MDF, OF and scrub classes) in the spatial distribution. When the forest type maps were being finalised, the forest cover map of 2005 assessment of FSI was available therefore the forest type maps generated from this exercise are based on the forest cover map of 2005 assessment of FSI.

9.2 Mapping of forest types is essentially a spatial exercise. Geographic information system (GIS) provides the ideal tool for mapping where use of several spatial layers in the analysis is involved. In mapping of forest types, several spatial layers like that of temperature, rainfall, soil, altitude, slope, satellite data etc. which relate to different factors responsible for the evolution of forest types, have been taken into account. The existing information resulting from different activities undertaken by FSI in the past, which had relevance to the forest types have also been used. Similarly, relevant information from other sources including SFDs has also been used. The information which was not available as thematic spatial layer has been brought into spatial reference by attaching it as attribute to the grid coverage of 2.5’ x 2.5’, referred to as ‘reference map’ in this exercise.

9.3 The mapping of forest types under this project is strictly according to the Champion & Seth Classification (1968). The description of forest types given in the literature has been translated into the maps by the analysis of different spatial layers, existing data, working plans, remote sensing data and ground observations in GIS framework. At no stage, review of any forest type, clubbing or splitting of forest types has been attempted. The methodology followed in the project has been discussed in the meetings of experts, Steering Committee, technical and financial sub-committee of NNRMS SC-B from time to time and suitable suggestions have been incorporated.

9.4 The following schematic diagram shows the steps of the methodology followed in the project. For each step, a procedure was developed after trials and discussions and the same was laid down in the form of manual for uniform application by the team of technical personnel engaged in the project. Brief description about each step has been given in the following sub sections.

10. Findings & Output

10.1 Forest type wise area figures have also been determined for 178 out of the 200 forest types at the district and State/UT levels. Area figures for the sixteen forest type groups of the country are presented in the table 4.1.

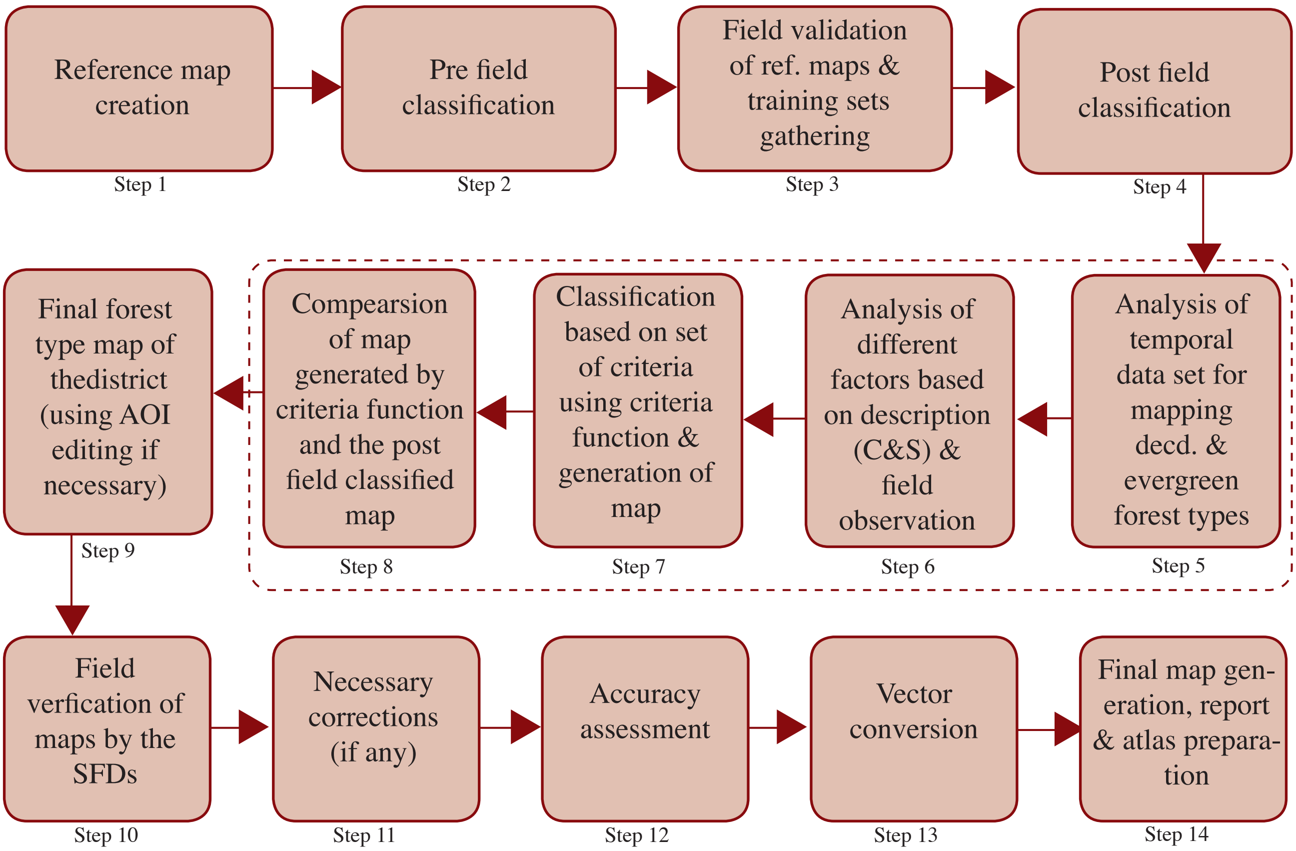


Table 4.1 Area under different forest type groups

S.No	Type Group	Area* (km²)	Percentage of the Total*
1	Group1 Tropical Wet Evergreen Forests	20890.09	2.92
2	Group2 Tropical Semi Evergreen Forests	94281.198	13.18
3	Group3 Tropical Moist Deciduous Forests	143192.01	20.01
4	Group4 Littoral & Swamp Forests	5035.89	0.70
5	Group5 Tropical Dry Deciduous Forests	294639.57	41.18
6	Group6 Tropical Thorn Forest	16183.21	2.26
7	Group7 Tropical Dry Evergreen Forests	929.38	0.13
8	Group8 Subtropical Broadleaved Hill Forests	19267.10	2.69
9	Group9 Subtropical Pine Forests	29953.31	4.19
10	Group10 Subtropical Dry evergreen Forests	196.06	0.03
11	Group11 Montane Wet Temperate Forests	5030.21	0.70
12	Group12 Himalayan Moist Temperate Forests	29483.88	4.12

13	Group13 Himalayan Dry Temperate Forests	5998.11	0.84
14	Group14 Sub Alpine Forests	9794.30	1.37
15	Group15 Moist Alpine Scrub	1678.99	0.23
16	Group16 Dry Alpine Scrub	3077.72	0.43
	Total	**679631.02**	**94.98**
17	Plantation/TOF	35931.59	5.02
	Total*	**715562.61**	**100.00**

**area under forest cover and scrub as per the SFR 2005.*

11. Map Products of the Project

11.1 The final maps of the forest types have been generated in five forms in terms of minimum patch size, format of the data or grid sizes. The rationale behind giving the output in five forms is to allow a user choice of appropriate forest type layer for his or her study. For example a user may prefer using 2.5' x 2.5' grid map while doing broad stratification based on forest types at the national level.

The forest type maps produced under this project are available in the following five digital forms

(a) 1 ha raster – the minimum patch size is 1 ha,
(b) 5 ha raster – the minimum patch size is 5 ha
(c) 5 ha vector – map in the form of polygons, the minimum polygon size 5 ha
(d) 1' x 1' grids – map in the form of square grids of size 1' x 1'
(e) 2.5' x 2.5; grids – map in the form of square grids of size 2.5' x 2.5'

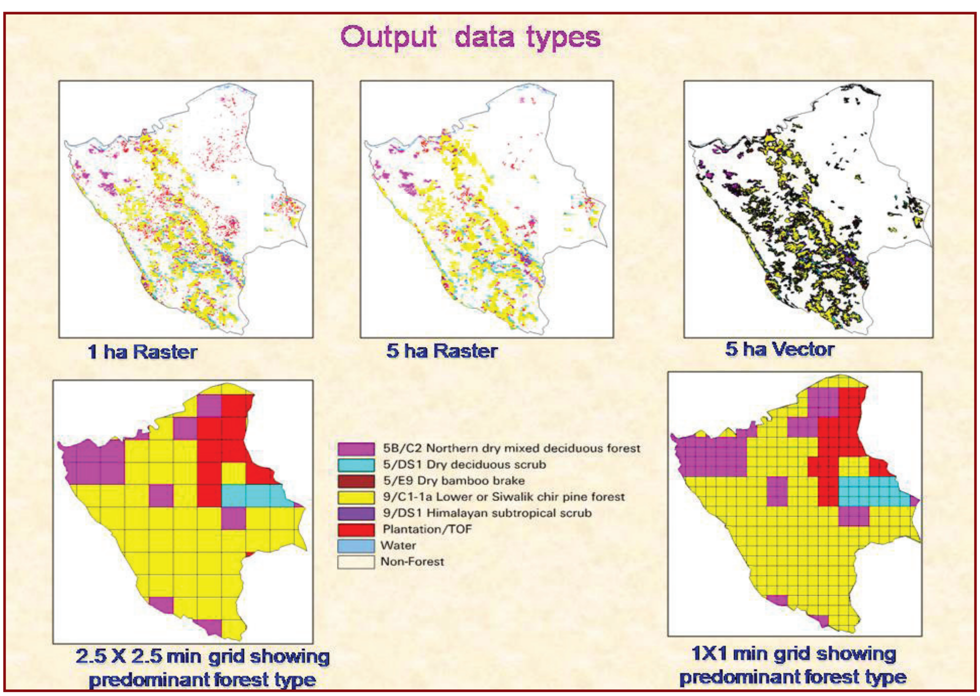
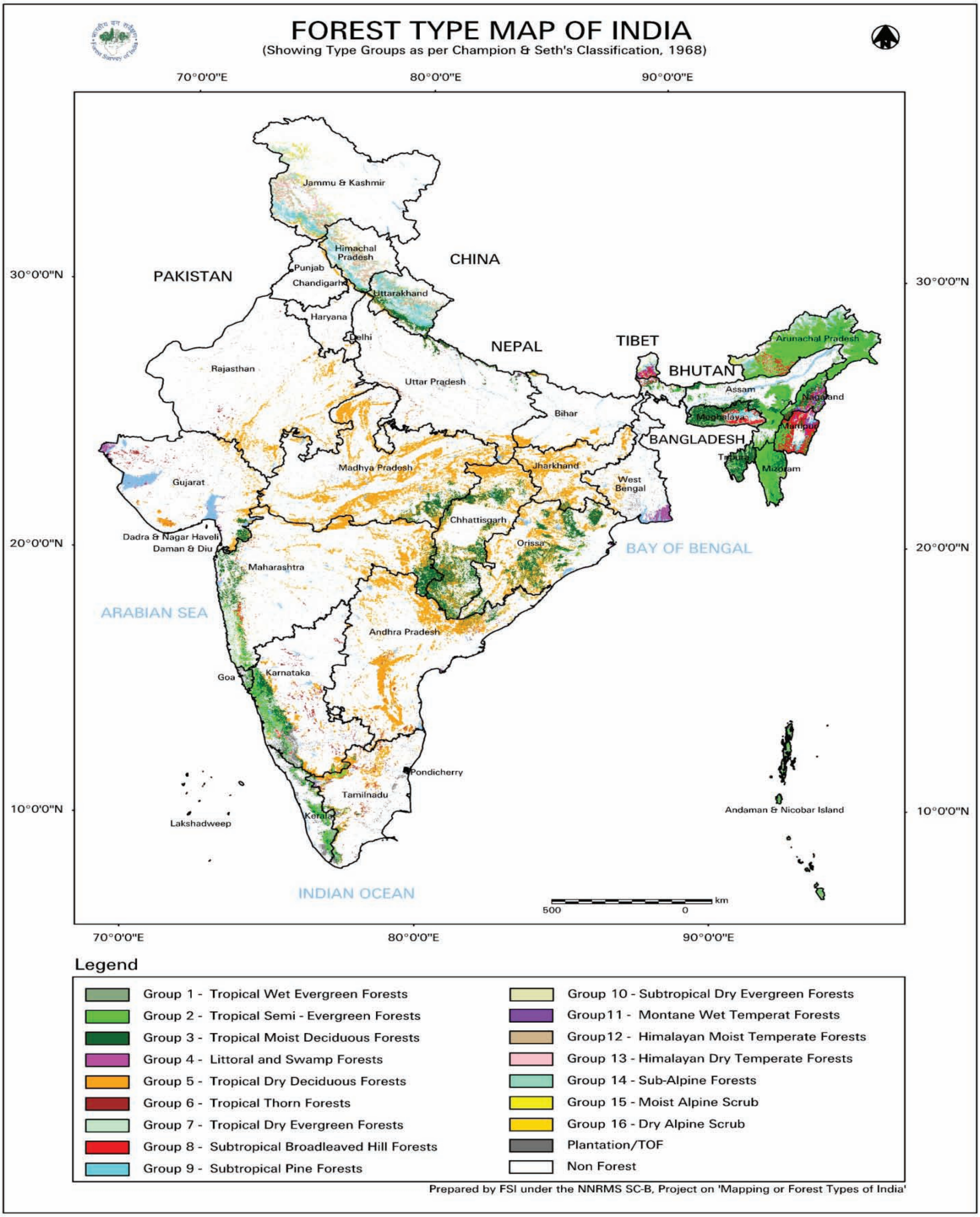


Fig 4.3 Forest Type Map Products


FOREST TYPE MAP OF INDIA
(Showing Type Groups as per Champion & Seth's Classification, 1968)
70°0'0"E
80°0'0"E
90°0'0"E
30°0'0"N
20°0'0"N
10°0'0"N
PAKISTAN
CHINA
NEPAL
TIBET
BHUTAN
BANGLADESH
Jammu & Kashmir
Himachal Pradesh
Punjab
Chandigarh
Uttarakhand
Haryana
Delhi
Rajasthan
Uttar Pradesh
Bihar
Arunachal Pradesh
Assam
Nagaland
Meghalaya
Manipur
Tripura
Mizoram
Gujarat
Madhya Pradesh
Jharkhand
West Bengal
Chhattisgarh
Orissa
Dadra & Nagar Haveli
Daman & Diu
Maharashtra
BAY OF BENGAL
ARABIAN SEA
Andhra Pradesh
Goa
Karnataka
Pondicherry
Tamilnadu
Kerala
Lakshadweep
Andaman & Nicobar Island
INDIAN OCEAN
500
0
km
Legend
Group 1 - Tropical Wet Evergreen Forests
Group 2 - Tropical Semi - Evergreen Forests
Group 3 - Tropical Moist Deciduous Forests
Group 4 - Littoral and Swamp Forests
Group 5 - Tropical Dry Deciduous Forests
Group 6 - Tropical Thorn Forests
Group 7 - Tropical Dry Evergreen Forests
Group 8 - Subtropical Broadleaved Hill Forests
Group 9 - Subtropical Pine Forests
Group 10 - Subtropical Dry Evergreen Forests
Group11 - Montane Wet Temperat Forests
Group12 - Himalayan Moist Temperate Forests
Group 13 - Himalayan Dry Temperate Forests
Group 14 - Sub-Alpine Forests
Group 15 - Moist Alpine Scrub
Group 16 - Dry Alpine Scrub
Plantation/TOF
Non Forest
Prepared by FSI under the NNRMS SC-B, Project on 'Mapping or Forest Types of India'

12. Accuracy Assessment

12.1 After completing mapping, an exercise of accuracy checking was undertaken on wide spread points. Accuracy assessment has been done using field observation data on over 3000 points spread across the country covering all forest types. The random points for this exercise were generated State wise in area proportion to size so that all the forest types are proportionally covered. These random points marked on the maps were sent to the SFDs for observing the forest type existing on the ground. The field observations about the forest types were taken by the State Forest Department personnel on the random points sent to them. While sending the random points for accuracy check, the forest type determined through this mapping exercise was not revealed to eliminate bias of any kind.

	Mapping																			
	Forest Type Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Pla/ TOF	NF	Total
Ground Observations	1	60										1								61
	2	1	93									1								95
	3	4	2	681	4	61		18	9											779
	4			2	54	1														57
	5		4	123	4	1927	16	13		1										2088
	6					17	83													100
	7							43												43
	8								51			7								58
	9					2				49			8		7		2			68
	10										9									9
	11											45								45
	12					1				3			69	11	5	8				97
	13													41			1			42
	14												1	6	62	5	3			77
	15															44	3			47
	16													1			47			48
	Pla/TOF	7	1	1	1	19						5						9		43
	NF		1	11		20	3		1	1		2	3					6		48
	Total	72	101	818	63	2048	102	74	61	54	9	61	81	59	74	57	56	15	0	

12.2 FSI has extensive sample plot data from the national forest inventory programme. Though sample plot data does not contain forest type specific details but the species composition and the location of the plot provides good information to deduce forest type of that point location. Details from about 632 sample plots were also used for the accuracy assessment exercise. Thus ground observations of a total of 3805 points were used for the accuracy assessment.

(a) Accuracy of the forest type map showing 16 type groups

Table 11.1 Error Matrix for the Forest Type Map in the 16 Type Groups

The over all accuracy of the forest type map in the 16 type groups at the country level is as follows

$$\text{Accuracy (\%)} = \frac{\text{Sum of the diagonal points}}{\text{total number of points}} \times 100$$

$$= \frac{3367}{3805} \times 100 \quad \text{i.e } 88.49\%$$

(b) Accuracy of the forest type map showing 200 types

Creation of error matrix for the forest type map showing 200 types was not practicable, therefore accuracy of forest type map has been assessed simply by taking ratio of the correct classification over the total number of points on which observations were taken. After compiling the results of field observations taken by the SFDs on the random points, it was found that the forest types shown on the maps were correct on 2950 points out of the total 3805 points giving an accuracy of 77.53%.

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Technical Session 7

FOREST GROWING STOCK/BIOMASS ESTIMATION

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1 Forest Growing Stock/Biomass Estimation

1.1 Growing stock (wood volume) in forest constitutes the basis for estimation of biomass in the forest and carbon stored therein. Forest growing stock has traditionally been a key indicator of forest health and productivity. Forest inventories are primarily aimed at assessing the growing stock of different species under different diameter class.

1.2 In India, systematic forest inventory began in 1864 when the preparation of working plan started and has remained central to the forest management at divisional/district level. The forest inventory on a relatively large area (catchment) basis using a statistically robust approach and aerial photographs began in 1965 when the Pre-Investment Survey of Forest Resources (PISFR) was launched in the country with FAO/UNDP assistance. The inventory in selected areas of the country was continued till 1981 when the PISFR was reorganized as FSI. Even after the creation of the FSI the field inventory remained the primary activity with a modified design covering the whole country. The total forest area inventoried until the year 2000 was about 69.2 million ha which included some areas inventoried twice. Thus, more than 80 percent forest area of the country was inventoried comprehensively in a period of 35 years.

1.3 A new National Forest Inventory (NFI) has been designed and adopted by FSI since 2002 to generate national level information on various forestry parameters for strategic planning of the forestry sector on every two years cycle. In every cycle, 60 districts, spread over entire country, are selected for detailed inventory of forest. The sampling design used for forest inventory has been explained in the subsequent paragraphs:

2 Sampling Design for NFI

2.1 The sampling design adopted for national forest inventory is two stages. In the first stage the country is divided into homogeneous strata, based on physiography, climate and vegetation called as physiographic zones and the civil districts form the sampling unit. There are 14 physiographic zones; Western Himalayas, Eastern Himalayas, North east, Northern plains, Eastern Plains, Western Plains, Central highlands, North Deccan, East deccan South deccan, Western ghats, East ghats, West coast and East coast.

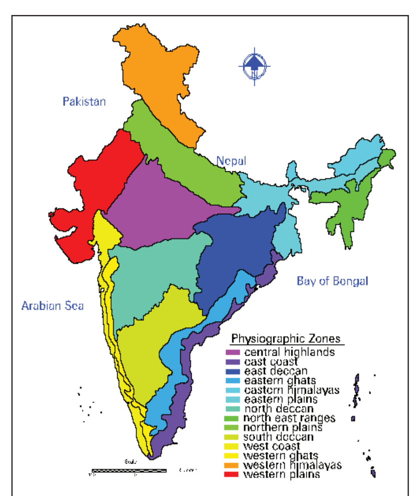


Fig.1: Physiographic Zone-wise Map of India

2.2 A sample of 10 percent districts (appxox. 60 districts in the country) distributed over all the physiographic zones in proportion to their size are selected randomly for detailed inventory of forest. In the second stage selected districts are divided into grids of latitude and longitudes which form the second stage sampling unit.

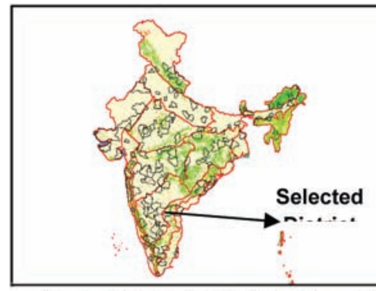


Fig.2: Selected districts of a cycle

2.3 For forest inventory in selected districts plots are systematically laid out in forest area which is indicated on topographic sheets by double dotted line, printed as RF, PF, thick jungle, thick forest etc, shown in green wash and any other area reported as forest area (generally un-classed forest) by the local Divisional Forest Officer.

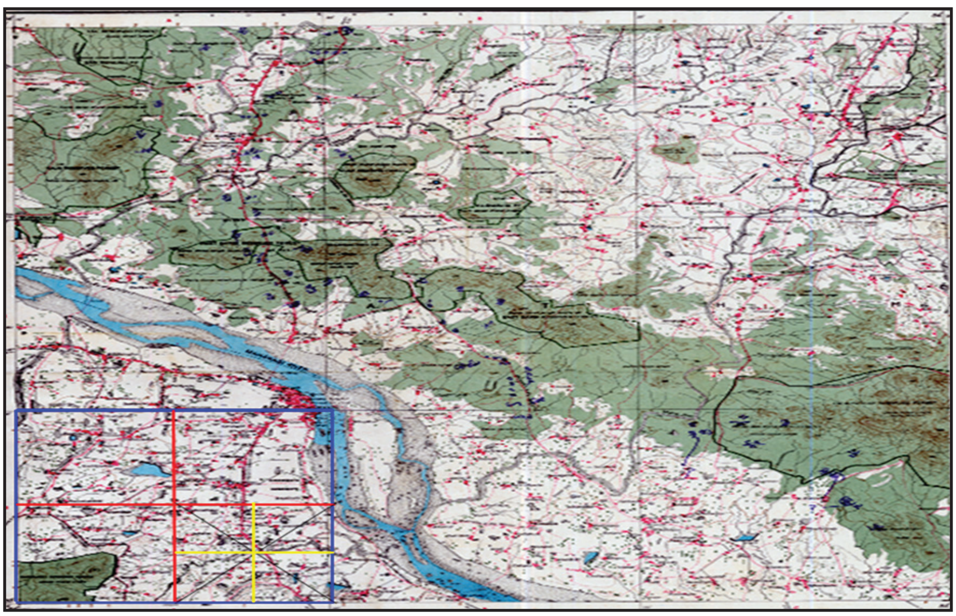


Fig.3: Scanned Toposheet of 1:50,000 scale

2.4 For each selected district, Survey of India (SOI) toposheets of 1:50,000 scale (size 15¢×15¢ i.e 15 minutes latitudes and 15 minutes longitudes) is divided into 36 grids of 2½¢×2½¢ which is further divided into sub-grids of 1¼¢×1¼¢ forming the basic sampling frame. Two of these sub-grids are then randomly selected to lay out the sample plots. Other forested sub-grids in the districts are selected systematicaaly taking first two sub-grids as random start. The intersection of diagonals of such sub-grids are marked as the centre of the plot at which a square sample plot of 0.1 ha area is laid out to record the measurements.

3 Organisational Structure and Responsibilities

3.1 The Forest Inventory Unit at FSI Headquarters, Dehradun is responsible for preparation of sample designs, selection of sample districts, designing of field forms, development of data entry and data processing modules and processing of field data for the inventory of forests, TOF and biomass study. The field work is executed by four zonal offices of

FSI located at Shimla, Nagpur, Kolkata and Bangalore for organising and conducting field inventory of north, central, eastern and southern part of the country respectively.

3.2 For forest inventory, the list of selected sample districts are sent to concerned zonal offices. The zonal offices are headed by Regional Directors and supported by Deputy Directors, Assistant Directors, Senior Technical Assistants (STA), Junior Technical Assistants (JTAs), Fieldmen and other supporting staff. The basic responsibility of officers/officials at zonal offices are to execute field work, data collection and data checking for the selected districts in their jurisdiction.

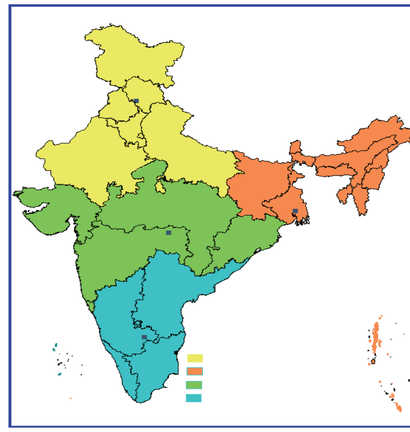


Fig.5: Jurisdiction under different Zones of FSI

4 Preparation of Field Work

General Preparedness

4.1 For carrying field work, field crew are formed comprising of 3-4 technical persons with one crew leader. The officer in charge of inventory distributes the work of inventory to the crews. Once the area to be inventoried is assigned to crews, the Crew Leaders select their camping sites in such a manner that maximum number of sample plots can be covered from a camp in the minimum traverse of distance. The day to day programme is meticulously chalked out to avoid any wasteful journey. The Crew Leaders ensure that their party are fully equipped with stores, camp and survey equipment, ration, medicines etc. before commencement of the field work.

4.2. As a general routine Crew Leaders keep good liaison with the local staff of the State Departments. The crew leader ensure that the tent camps are properly, neatly and systematically arranged and the staff maintains decorum and proper discipline in the camps. The restricted maps and photographs and confidential documents in the camp are kept safely and are not shown to any un-authorised person. Such documents are kept in personal custody of Crew Leader. In case of any loss or damage to any such map or photograph the crew leaders are supposed to report the matter immediately to the Regional Director of the Zone.

4.3 Equipment and Other Materials Required for Each Field Crew

S.No.	Equipements and other materials	Number Required	Additional Comments
1.	Silva compass	1	
2.	GPS handset with extra batteries	1	
3.	Hypsometer/Hagaltimeter for measuring trees height	1	
4.	30-50m (self-rolling) measuring metallic tape or rope/chain, marked at every 1-5 meters)	1	- Metric
5.	Steel scale (6 and 12 inch)	1 each	
6.	Digital Camera + spare memory card + extra batteries + charger	1	
7.	Coloured flagging tape	Several rolls	Used for marking
8.	Waterproof Bags	2	To protect equipment against water/rain
9.	Wooden Callipers	1	Metric
10.	Weighing Machine	1	Digital
11.	Axe and handsaw	1 each	
12.	Pathal/Khukhri	1	
13.	Plastic bags	1	For soil sample
14.	Topographic maps and field maps	As necessary	
15.	Field forms	As necessary	
16.	Field manual	As necessary	
17.	Note books	As necessary	
18.	Pens & markers including marking pencils	As necessary	
19.	Hand calculator	1	
20.	Camping equipment & cooking utensils	As necessary	
21.	Food items	As necessary	
22.	Herbarium press	1	For un-identified species of herbs and shrubs
23.	Vernier Callipers	1	For measuring dia meter of herbs and shrubs

Preparation of Field Forms

4.4 The Crew Leaders ensure that adequate field forms are carried in field and each member has understood the field manual properly to have a clear understanding of the works to be done in the field. All doubts regarding field work are fully cleared before proceeding to the field.

Preparation of Field Maps and GPS

4.5 Only the latest published topographic maps of 1:50,000 scale are used. However, if the maps are not available on this scale the alternative maps like grey prints, or bromide prints or even 1^{2} = 1 mile scale maps are used during survey. A precaution has to be taken that no area is left unsurveyed for the non-availability of maps. The maps are temporarily borrowed if required, from the Local Forest Departments if these are not available with any other source.

4.6 The hand held GPS used for approaching sample plots are checked properly and ensured that batteries are new and instrument is working properly. The necessary training for using GPS are given to Crew members. The latitudes and longitudes of sample plots are fed in GPS to navigate to the sample plots.

5 How to Reach the Sample Plot

5.1 Once plot number and grid number to be surveyed is decided, the Crew Leaders approach the sample plots with the help of GPS. In case GPS is not working due to any reason reference point is marked as follows:

6 The Reference Point and its Marking

6.1 The reference point selected on a map should be such that it is not a temporary structure which may disappear within a year or two as the same is required to revisit the plot in the future. Usually the following features are liable in adopting as reference points.

1. Bench mark
2. Triangulation points
3. Village tri-junction points
4. Old bridges and culverts
5. Old temples, mosques and churches
6. Crossing of rail track with roads, rivers, streams
7. Junction of rivers or streams and roads
8. Prominent bends in roads, rivers, streams
9. Old ponds and wells
10. Springs
11. Prominent topographical features in hilly area such as spurs, knots etc.
12. Mile stones or kilometer stones
13. Boundary pillars (of International, State, District and forest).

6.2 As far as possible small nallas less than 6 metre width and rough roads or foot paths are not selected as a reference point. The Crew Leaders may select any of the above features, which is most prominent on the map.

6.3 The location of reference point and its correct description recorded in the form is very important for re-visiting the sample plot in future.

6.4 After identifying the reference point in the field, a permanent structure or a prominent tree facing the reference point is also identified. A blaze of 15cm × 15cm is made on the tree at breast height by removing the bark. The following details are recorded in red paint/red jet pen on the structure/tree.

1. Grid Code
2. Mapsheet Number
3. Bearing from reference point to the plot centre as obtained from topographic map
4. Distance of plot centre from reference point in kilometers as obtained from the topographic map
5. Initials of Crew Leader
6. Date of survey
7. Distance and bearing from two nearly prominent trees or structures to the reference point.

6.5 In addition to these the following recordings are made on the back side of the plot approach form.

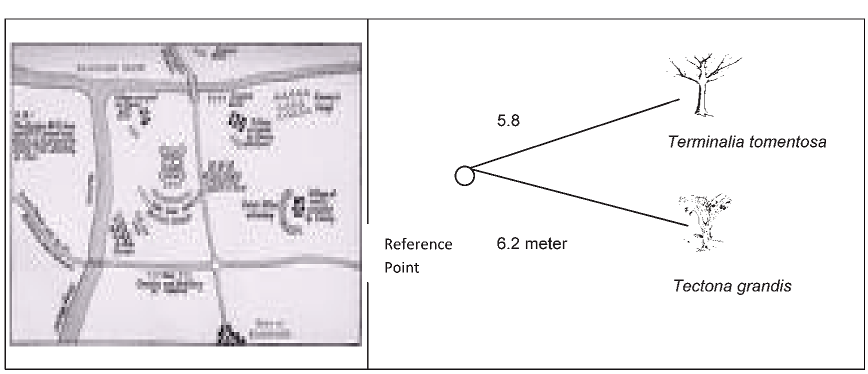
A) A free hand diagram of nearly 10 cm x 10 cm size showing the reference point and its surrounding prominent features. This is specially useful for locating the junctions of small nallas, roads etc. which are adopted as reference points by the Crew Leaders (see illustration below).

B) A rough diagram of nearly 10 cm x 10 cm showing distance and bearing from two nearby prominent trees or structures to the reference point (see illustration below).

Preferably the names of trees should be given on the diagram.

6.6 For example in sketch 'A' shown below, the tri-junction of the road has been taken as reference point. In sketch 'B', two prominent trees with their names and distance from reference point has been shown.

A B



7. Ranging to Sample Plot Centre

7.1 At the reference point, the bearing of compass is set towards the centre of the sample plot. The crew leader then moves towards the centre and measures the horizontal distance as provided by the topographic sheet. For the ease in further checking the trees along the bearing line, small blazes are given at breast height.

8. Field Plot Measurements and Observations

8.1 After reaching the plot centre, some of the qualitative information are recorded occularly within an area of 80m radius from the plot centre without actually laying out the plot. The information collected are land use, legal status, crop composition, soil, grazing, fire etc.

9. Layout of Sample Plot in the Field

9.1 The plot centre is reached after covering desired distance and bearing from the reference point which represents the centre of the plot of 0.1 ha. i.e. the point of inter section of two diagonals i.e. NE to SW and NW to SE of the plot. The length of each diagonal measures 44.72 m. After reaching the plot centre, a stout peg of approximately 10 cm diameter and 1.5 m height is put at the centre, blaze it at the top and fix it firmly on the ground facing the blazed surface towards the direction from which sample point was approached. The sample point reference number and the date is written on the blazed surface. Two nearby prominent trees are selected preferable at right angles from the peg for permanent referencing of the sample point. On each reference tree a blaze is given at the breast height facing the peg and the following references are written.

1. Grid code
2. Mapsheet number
3. Initials of Crew Leader with date
4. Distance and bearing from two nearby prominent trees or structures to the plot centre. These details are also recorded on plot approach form.

9.2 After reaching the plot centre, from true north fix the NE at 45^0, SE at 135^0, SW at 225^0, NW at 315^0 corners of the plot by measuring 22.36 m. horizontal distance, i.e. half of the diagonal, by distance measuring tape in all four directions. These four corners are marked by thin poles or bamboos of 5 cm dia. and 1.5 metre in height. If possible ranging rods also are used as corner posts. A red colour cloth is tied at the top end of these corner posts for getting clear visibility from different spots in the plot. Check the dimensions of the plot i.e. all sides should measure 31.62 metres horizontal distance. Due care is taken to adjust the dimensions of the plot according to slopes as given in the field manual.

10. Layout of Sub Plots

10.1 Within sample plot, sub plots of 1m x 1m are laid out at NE and SW corner for collecting data on soil, forest humus. To lay out the sub plots 1.42 m is measured from the corner of the sample plot along the diagonal towards its centre then sides of sample plot are joined.

10.2 The data on herbs and shrubs including regeneration are collected from four square plots of 1m x 1m and 3m x 3m respectively. These plots will be laid out at a distance of 30 meters from the centre of 0.1 ha sample plot in all four directions along diagonals in non-hilly area and along trails in hilly areas. In case of hilly areas the plot are taken randomly 3-10 meters away either side of the trail as shown in the diagram. Now to lay out 1m x 1m square plots for herbs/shrubs whose centres are marked at 30 meters from the centre of 0.1 ha plot, mark four points at the distance of 0.71 meter along diagonal in both sides and at right angles. Join all the four points. Similarly, for shrubs and regeneration square plots of 3m x 3m are laid out at the same centre by marking and joining four points at 2.12 meters distance along diagonal and at right angles.

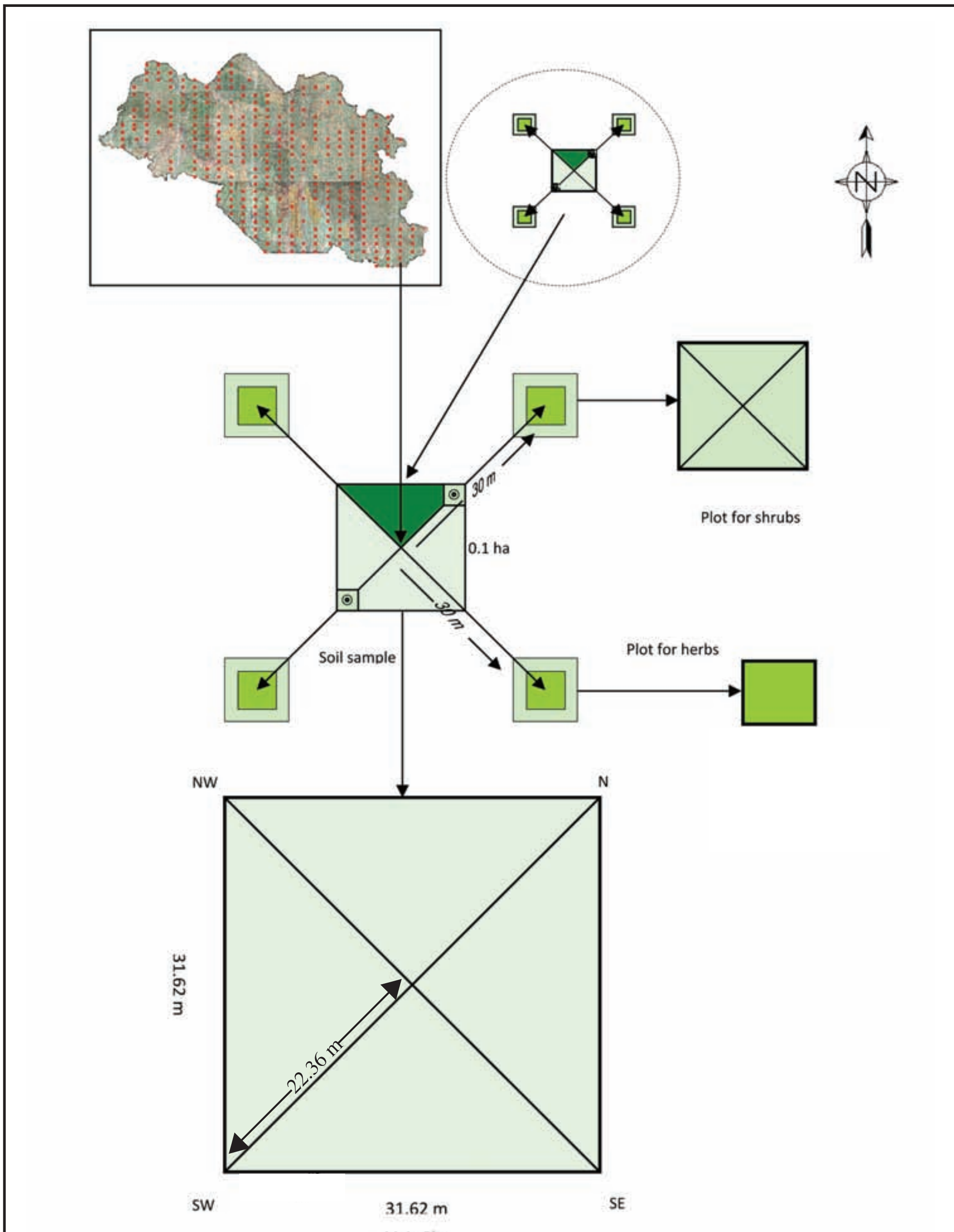


Fig.7: Description of Sampling Unit

11. Data Collection

11.1 After demarcating the plot and after satisfying that it is correctly oriented the Crew Leader collects the data in prescribed forms. Instructions for filling different forms are given in the manual. The crew leader is personally responsible for data to be collected and he may assign duties to other crew members as per choice (considering the efficiency of every member of the team).

The following precautions are be taken while collecting data.

1. The data should be collected accurately with the help of the members of Crew and should be recorded neatly in as good hand writing as possible in the proper field forms by the crew leader himself, in the field.
2. The code numbers should be neatly and correctly recorded in legible manner.
3. Over writing of codes should be avoided. Wherever any mistake is committed in writing the first entry should be cancelled and a corrected entry should be written duly attested by Crew Leaders.
   The digits should be written as under
   1, 2, 3, 4, 5, 6, 7, 8, 9, 0
4. Filling of Forms in Hindi, Urdu or regional languages should not be adopted without approval from the Head of the Office.
5. The data will be collected and recorded in the following field forms.

Field Form No.	Item	Form Code
1.	Plot Approach Form	00
2.	Plot Description Form	01
3.	Plot Enumeration Form	02
4.	Sample Tree Form	03
5.	Bamboo Clump Analysis Form	04
6.	Bamboo Enumeration and Analysis Form (non-clump forming)	05
7.	Bamboo Weight Form	06
8.	Herbs, Shrubs and Regeneration Form	07
9.	Soil and Forest Floor Carbon Form and Soil and Forest Floor Sample Card	08

6. Detailed instructions for filling up of these forms are given in the field manual.
7. If complete data of a plot does not get accommodated in one sheet a second sheet should be used as continuous and the additional sheet would be carefully tagged with the main form after filling all columns and clearly write the words ‘continuation sheet’ on the second and onwards pages.
8. Before leaving the plot see that no instruments or stores are forgotten.

9. See that the plot is left as clean as it was before entering it.
10. See that all members who have assisted in recording the information sign and write their names on the form.
11. Please see that all information is recorded/written and measured in field itself and nothing is taken to camp for compliance. Once a plot is left it should be presumed that all jobs of recording, filling forms, muster rolls etc. are completed in all respects.
12. Random check for about 10% sample points in each district should be carried out by the higher authorities.

12. Data Entry

12.1 Once data is collected in various field forms, it is entered into the computer using data entry module developed by FSI. The data is stored in the access database. The entered data is checked manually as well as using computer generated programs for any kind of error committed at the time of recording in the field or during data entry. The data is cleaned before processing.

13. Data Processing

13.1 For processing of forest inventory data, the inventoried plots in selected districts were classified according to legal status, i.e. recorded forest and private forest. Then per plot area (area factor) is calculated on the basis plots in recorded forest area. These plots are further classified into different density classes and other land uses. They are then grouped into two broad classes; vegetated (very dense, moderately dense, open & plantations) and less vegetated (scrub, shifting cultivation areas etc.) The area under these classes is calculated using area factor. The plots corresponding to vegetated area are post stratified according to crop composition (stratum) based on dominant species appearing in a particular district. Plot volume is then calculated with the help of volume equations developed by FSI for each tree species found in the plot. At district level, all sample plots are combined according to crop composition, which is used to estimate growing stock at different levels.

13.2 To estimate the growing stock at physiographic zone level, area under each stratum is first estimated. Thereafter, per hectare figure of growing stock for each stratum is used to estimate the growing stock of the physiographic zone. This process is repeated for all physiographic zones. Summing up of growing stock of all the physiographic zones will yield the growing stock of forests for the whole country.

14. Volume Equations:

14.1 Volume equations for different species found in different part of the country are already generated by FSI. For preparation of volume equation of a tree species, efforts should be made to cover a good range of available diameter. Generally thirty or more trees are measured for this purpose. The trees for the measurement are selected randomly. Two diameters at breast height (1.37 meter from ground level) are measured, at right angles to each other. These measurements are recorded over bark. The height of the tree is measured with the help of Hypsomete/Clinometer. The diameter is recorded to the nearest millimeter and height is considered as such after computation. Thereafter tree is felled. The first log is marked at 2.74 m keeping the breast height mark in the centre and taking the girth as mid girth of the first log. The rest of the bole is divided into sections of 3 m length and mid girth of each section is recorded. The last section is allowed to vary between 2 to 4 meters. The lower diameter limit fixed for the measurement is 10 cm. The volume of individual log is calculated by Huber's formula, which considers the cross sectional areas of the log at mid-point as a circle and when multiplied with the length of the log it gives the volume. The volume of all the logs produced by a tree is added together to get the volume of the tree. The regression equations were developed using standard software package between volume of trees and diameter (some time with height also).

Vol = f (dbh, h)

Where f = function of dbh= Diameter at breast height, h= height

Volume equations are selected on the basis of R^2 (coefficient of determination), adjusted R^2, Standard error of model, Analysis of variance, testing of regression coefficients, analysis of residuals etc.

15. Biomass and carbon stock

15.1 The final output obtained from forest inventory is the number of stems and their volume for different species according to different diameter class at the national level. The volume is converted into biomass using specific gravity of different species obtained from various research papers. To convert biomass data into carbon, carbon content percentage in different species was estimated from FRI. The biomass estimates are multiplied by carbon content percentage to obtain the carbon stock in different species.

Technical Session 8

ESTIMATION OF SOIL ORGANIC CARBON

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1. Introduction

1.1 For the past four billion years the exchange of energy between the surface and atmosphere of the Earth and with space has generally been in balance. The carbon dioxide and other greenhouse gases that are released by plants, decomposition and human activities has been in balanced with the carbon dioxide absorbed by terrestrial vegetation and oceans. However, there has been a dramatic increase in the amount of these greenhouse gases since the early 1900's that can be linked to the industrial revolution. Burning of fossil fuels, increasing agriculture, deforestation, landfills, industrial production and mining contributes to the emissions of GHGs (Anon., 2008). Concentration of atmospheric CO_2 can be lowered either by reducing emissions or by taking CO_2 out from the atmosphere and stored in the terrestrial, oceanic or aquatic ecosystems. Tree growth serves as an important means to capture and store atmospheric carbon dioxide in vegetation, soils and biomass products (Makundi and Sathaye, 2004). After the litter fall, the detritus is decomposed and forms soil organic carbon by microbial process. Soils and vegetation, therefore, represent potential sinks for this additional carbon and several authors have suggested afforestation as a possible means of mitigating global climate change (Shivanna *et al.*, 2006 and Ramachandran *et al.*, 2007). Several studies have established the fact that carbon sequestration by trees could provide relatively low cost net emission reductions (Plantinga and Birdsey, 1995; Callaway and Mc Card, 1996; Stavins, 1999). Intergovernmental Panel on Climate Change has recognized soil organic carbon pool as one of the five major carbon pools for the Land Use, Land Use Change in Forestry sector.

1.2 Soil plays an important role in the carbon cycle by storing it in the form of soil organic carbon. Soil especially, the forest soil is one of the main carbon storage pools on earth because these soils normally contain higher soil organic matter. Soil Organic Carbon (SOC) has been ignored since long because it was treated as a dead biomass and it has acquired the importance after the Climate Change awareness. Soil contains an important pool of active carbon that plays a major role in the global carbon cycle (Melillo *et al.* 1995, Prentice *et al.,* 2001). Soil carbon has much longer residence mean time than the Carbon in the vegetation that the soils support. Storage of organic Carbon in this long residence time pool is referred to as Carbon sequestration.

2. Accurate Quantification of Soil Organic Carbon:

2.1 Accurate quantification of soil Carbon is necessary for detection and prediction of changes in response to changing global climate. However, some investigations have been carried out and data generated on the soil organic carbon pool in the forests, but the data is incomplete and non coherent. In several cases, as noticed in the literature, the researcher has estimated soil organic carbon simply as one of the soil attributes depending upon their objectives of the study. The depth of soil sampling and method of analysis varies from study to study as per the objective of their project.

2.2 Most of the data in literature is in the form of per cent soil organic carbon. Whenever it is converted into soil organic carbon pool / store, some assumptions have to be used especially for calculation of weight of the soil. Chhabra *et al.* (2002) have attempted to estimate the soil organic carbon in India based on different forest types, but the bulk density, which is the key factor for soil organic carbon estimation has been calculated indirectly in their method. Therefore, uncertainty in this type of data occur. No systematic study has been undertaken to estimate the soil organic carbon pool in forests, as well as in other land uses by following uniform methodology for field and laboratory work. Of course, initiation to estimate SOC pool as per guidelines of IPCC has now been started to produce authentic and comprehensive estimates of this important parameter. Detailed methodologies of carbon estimations like in vegetation, litter, soil etc. have also been given by Ravindranath, N.H. and Ostwald, M. (2008) in his book “Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Round wood Production Projects”.

3. Estimation of Soil Organic Carbon:

For proper estimation of soil organic carbon, all the steps from selection of location to calculation of SOC pool are very important and should be performed very carefully.

3.1 Location: Select an appropriate location in the forest area, to collect soil samples for estimation of Soil organic carbon. While selecting the location, certain points should be kept in mind:

- Locate sample site away from roads, houses and construction sites, etc.,
- In a forested area sample should be drawn away from the trunk of the tree
- Avoid eroded and locations where large plant material is under decay.
- Always dig a fresh pit to collect soil samples.

3.2 Selection of sampling sites
Minimum three sampling points should be selected under each location, as replicates. In each sampling point, soil sample of 0 - 30 cm depth should be collected. These points should be spreaded in the forest area in such a way that they may represent the variations of the forest area.

3.3 Recording of site features
Following features of all the sampling sites should be recorded:

i) Location of the sampling point including latitude, longitude, altitude
ii) Vegetation including over and under story
iii) Slope (Convex or concave)

iv) Litter status
v) Erosion status
vi) Moisture status
vii) Soil depth
viii) Any other special feature of the site

3.4 Collection of soil sample for carbon estimation
Forest floor litter of an area of 1.0 m x 1.0 m, at sampling point should be removed and a pit of 30 cm wide, 30 cm deep and 50 cm in length dug out. Soil from three sides of the pit of 0 to 30 cm depth, should be scraped with the help of Kurpee and collected. This soil is mixed thoroughly and about 500 g soil should be collected for analysis. Keep in a polythene bag and tightly closed with thread and labeled properly.

3.5 Collection of soil sample for bulk density estimation
Insert the bulk density core (of known volume) in between 0 – 15 cm depth with the help of Hammer, up to the top of the core. Remove the core carefully so that the soil inside the core may not drop down. Collect the entire soil in a polythene bag and bring it to laboratory. Repeat this exercise again in the soil 15 – 30 cm depth. Keep these soils in oven at 65 ^{0}C till it is completely dried. Measure the dry weight of the soils and calculate the bulk density of the soil.

3.6 Bulk density of the soil (g/cc) = Dry weight of the soil (gm) / Volume of the core (cm^3)
Finally average of both the above densities should be taken for final calculation of the soil weight of that particular site for 0 – 30 cm.

3.7 Estimating Percent Course Fragment in the Soil
Percent coarse fragment (> 2mm size) in soils should be estimated to work out the correct soil weight. After taking the weight of the dried sample for bulk density, the sample is put in the 2 mm sieve and run the water over it. Soil particles less than 2 mm will go away with water. Take out the course fragments from the sieve and dry it and weigh it. Calculate the percentage of the coarse fragment.

3.8 Preparation of the sample for Soil Organic carbon estimation
Open the polythene bag and spread the samples on a brown paper sheet in the laboratory. Let the sample dry at room temperature in the laboratory. ***Avoid direct sun drying or oven drying.*** After drying the samples, grind it and sieve it through 100 mesh sieve. The sieved sample will be used for soil organic carbon estimation.

3.9 Analysis of the sample for Soil organic carbon
Estimate the soil organic carbon content by standard Walkley & Black method.

3.10 Estimation of Soil Organic Carbon pool:

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

Horizon = n   Horizon = n

SOC =   SOC horizon =   ([SOC] * Bulk density * depth * (1 – frag) * 10) horizon
Horizon = 1   Horizon = 1

Where,

SOC = Representative soil organic carbon content for the forest type and soil of interest, tones C $ha.^{-1}$

$SOC_{horizon}$ = Soil organic carbon content for a constituent soil horizon, tones C ha^{-1}

[SOC] = Concentration of SOC in a given soil mass obtained from analysis, g C $(kg\ soil)^{-1}$

Bulk density = Soil mass per sample volume, tones soil m^{-3} (equivalent to Mg m^{-3})

Depth = Horizon depth or thickness of soil layer, m

C Fragment = % volume of coarse fragments / 100, dimensionless

3.10.2 There is a major potential for increasing soil organic carbon through restoration of degraded soils and widespread adoption of soil conservation practices. The variety of soils occurring in India offers different potential for carbon sequestration. They also need different sets of strategic management for improving their mitigation potential because of their different mineralogical, biophysical and chemical behaviour and response to a given input. The soil management alternatives should, therefore, be compatible with the land use on one hand and with the nature and the extent of the soil groups in the country on the other.

3.10.3 There is a need to formulate a strategy for SOC estimation and monitoring under different forest covers and also under the Trees Outside Forest (TOF). Major considerations for soil management are to develop knowledge bank on geological/ mineralogical, physical, chemical, biological and microbiological properties and the inter-linkages. The regional specificity of soil behaviour could then be understood and managed for finally stabilizing GHGs nationwide on a sustained basis.

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Technical Session 9

COMPLEMENTARY COMPONENTS OF FOREST BIOMASS

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1. Introduction:

1.1. The comprehension of existing situation and future requirements triggers the planning process of renewable and non-renewable natural resources at particular epoch. This understanding drives the information needs for the planning and accordingly surveys are planned to generate desired information with desired level of accuracy and precision.

1.2. During nineteenth century the concept of management of forest resources started which necessitated the generation of quantitative information about various parameters of forest resources with the popular concept that if you cannot measure you cannot manage. In the year 1863, a document "Manual of Forest Operation" was prepared for systematic collection of data related to the working of the forests which paved the path of today's "working plans". The mapping of forest area was also started by Survey of India and after 1910, forest mapping were made ancillary to topographical surveys.

1.3. Statisticians in developed countries were trying different sampling designs for forest inventory ranging from simple random sampling, stratified, systematic cluster and probability proportional to size. Few of them were also trying using the aerial photos. Most of the statisticians were of the opinion that the best approach is to use aerial photo plots and ground plots in combination to estimate areas and volumes. In this methodology aerial photos are used to form strata and to estimate their sizes along with a sub sample of those plots will be measured as field plots. This is a double sampling design or may be called as stratified sampling with estimated strata sizes.

1.4. Forest Inventory means the procedure of obtaining information on the quantity and quality of the forest resources and many of the land area on which the trees are growing. Thus the reports contained the information not only on the species and dia class wise growing stock, actual utilizable wood and bamboo etc. but also contained information about accessibility, transportation, infrastructure, description of topography, preservation of survey results by way of mapping etc. which was felt necessary for the industrial units interested in putting up their manufacturing units.

1.5. Precision of estimates which is influenced by man-power, cost, time and permissible error, is the key factor while designing the forest inventory. Similarly, suitable plot size and shape, optimum sample size has its impact on the requirement of man-power, cost and time for a given level of precision. All these parameters are function of heterogeneity of the forest resources available in the study area. To understand the level of heterogeneity pilot surveys are conducted and above parameters are estimated. Based on which suitable sampling designs are ascertained for a particular study area. During 1965 to 1980, systematic cluster sampling was used in general. The study area was divided into suitable grid sizes (5'x5' or 2-1/2'x2-1/2') depending upon the optimum sample size (which defines the sampling intensity) and within the selected grid a cluster of 3 to 8 sample plots were considered for recording the data on different parameters inventory. Whenever the information on stratification variable was available, stratified random sampling was used, otherwise the collected data was post-stratified to increase the precision of estimate.

1.6. During the last decade of 20th century, the role of forests was redefined by including the additional parameters like **carbon sequestration in plant community and in forest soil**, bio-diversity, regeneration status, NTFP etc. FSI came out with an integrated approach in 2002-03 in which forest inventory with provision of capturing above mentioned parameters would be conducted in a cycle of two years. This approach is being followed and the estimates are being improved cycle after cycle.

2. Carbon related variables of National Forest Inventory (NFI)

2.1 The emerging scenarios demand data on new variables. Any approach cannot foresee all the data needs of the future. The NFI does not provide information on all the components related with carbon but on the following:

- Above ground woody component of trees having dbh 10 cm or above,
- Bamboo biomass,
- Regeneration data,
- Bark,
- Litter and humus, and
- Soil organic carbon.

3. Complementary components for forest carbon

There are number of other components which contribute their bit in the total forest carbon stock. Before deciding if additional components should be included or not, its consequences on international reporting should be examined. Since, once it is reported then the same components have to be included in subsequent reporting as well. If the assessment cannot be done for future reporting then it is advisable to use national or global default values. For obvious reason it cannot be done for a key category. However, it is also advisable that once a component is selected for reporting, default values could be used initially and should be improved in subsequent reporting.

3.1 Following components are generally out of the purview of any inventory/assessment/ monitoring mechanism:

3.1.1 Biomass of stem below 10 cm diameter and branches below 5 cm: in NFI all the trees having dbh 10 cm or above (country specific) are enumerated. The species wise volume equations are used to estimate the volume of the tree. These equations give the estimated volume of wood in the tree for a particular dbh. But the estimated volume of wood include the volume of wood in main stem up to 10 cm diameter (country specific) and also include the volume of wood contained in branches up to 5 cm of diameter (country specific). These limits were prescribed to include the volume of wood having timber value. Therefore, the biomass contained in stem below 10 cm diameter and contained in branches below 5 cm diameter, may be termed as **biomass of small wood**, is missing and should be estimated.

3.1.2 Biomass in foliage of trees having 10 cm dbh or more: The information on **biomass of foliage**, flowers, fruits and twigs of the enumerated NFI trees are also not available. To capture these information, it is adequate to develop biomass equations taking dbh as independent variable and biomass of these component as dependent variable. Once these equations are developed then using these and dbh of enumerated trees, biomass of each enumerated tree can be estimated for small wood and foliage.

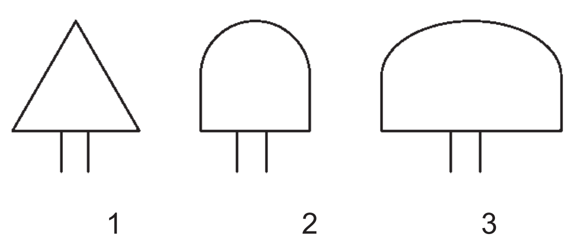
3.1.3 Under the National Forest Inventory (NFI) programme or through any other assessment mechanism, important tree species from the biomass angle, should be identified. For example, FSI is conducting NFI and is collecting and analyzing the sample plot data from forest lands distributed across the country in different physiographic and climatic zones (14 in number). Data from about 21,000 sample points, have already been collected during 2002-2006 as per the sampling design. At each sample plot all tree species of diameter 10 cm and above were measured. The volume of each sample plot was calculated using volume equations developed by FSI for various species. Through this information, in each physiographic zone, 20 important tree species have been identified.

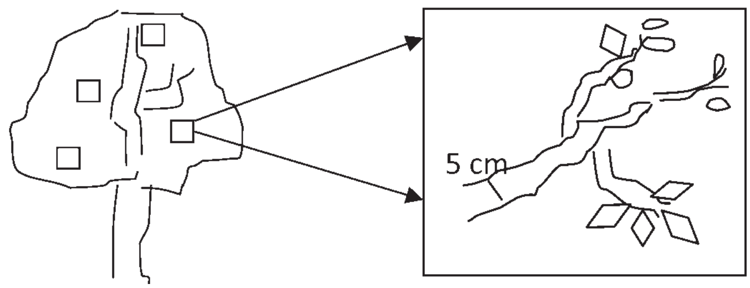
3.1.4 FSI undertook a study to develop biomass equations of small wood and foliage, for each such species other than palm like trees. Since strata wise (physiographic zone) important tree species were identified, many species were featuring in many strata, which will provide additional information that biomass of same dbh is same or different in different zones. The classical approach of developing biomass equation demands for destructive sampling involving felling of trees. In addition, the process is very tedious and therefore a new method which required lopping off, at the most few branches of few trees, was developed. With the analysis of NFI data, dbh range was ascertained for each of the species. Dbh of most of the species were ranging from 10 cm to 90 cm. Therefore, it was decided to make dbh classes of 10 cm interval starting from 10-20, 20-30,……,80-90 and 90+.

3.1.5 To collect data for this purpose separate formats were devised. In each of the diameter class, three normal trees are selected. The normality is defined with respect to that forest. The tree chosen for data collection should represent the general condition of that species in that forest. Its dbh, height, crown length, crown width in two direction and shape of the crown is recorded. In addition, canopy blank in that tree is also recorded.

3.1.6 For the purpose of biomass calculation one normal tree of each diameter class of each species is selected. In the selected tree one square meter window in all the four directions is opened in the crown until woody branches of 5 cm. dia is reached. All such material from window is felled i.e. woody branches up to 5 cm dia, twigs, leaves, fruits and flowers. Biomass of all these parameters is separately recorded in the prescribed formats. A small piece of wood and small amount of foliage is kept for drying and estimating carbon content percent. Sometimes it is not possible to open the window in the crown. In that case, four branches of different directions are lopped. At the ground it is tried to make similar projection as if it is still attached to tree and open a window of one square meter and rest of the process is same. For palm like species two leaves are felled from each tree in each diameter class and their weight and total number of leaves in those trees is counted and recorded for biomass calculation.

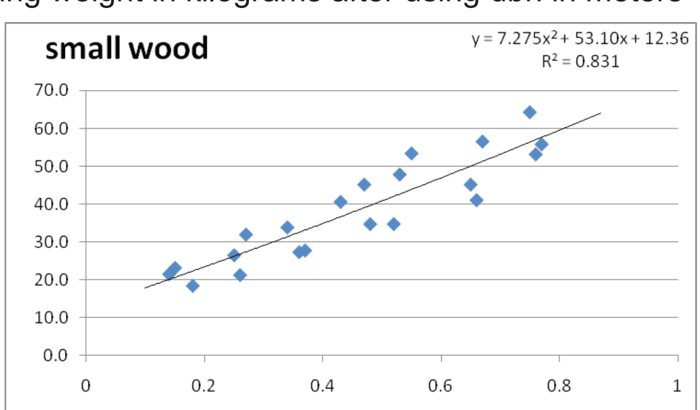
Table1: showing the items to be recorded

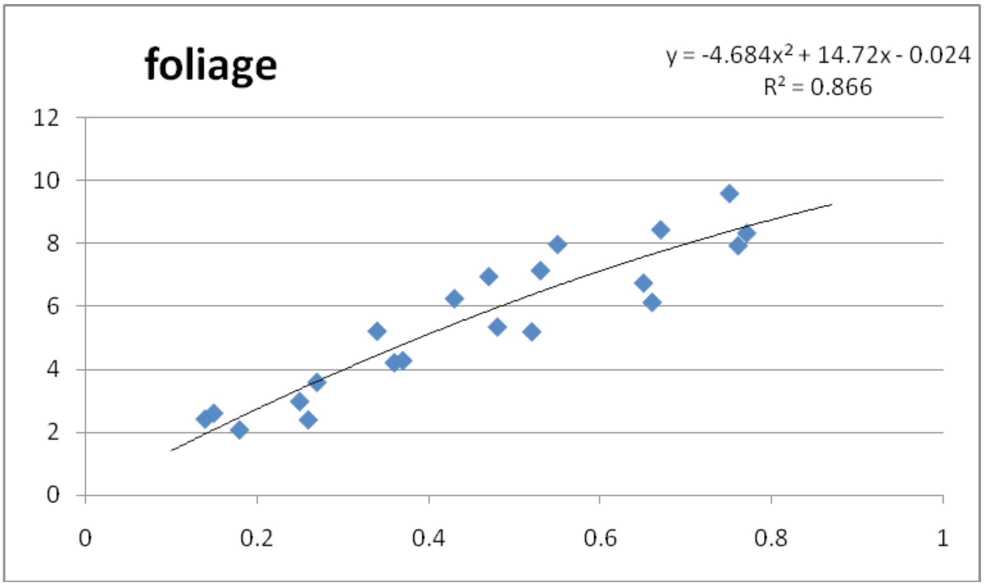
1.	Species Name & Code	The name of the species for which data is being collected along with its code is to be recorded.
2.	dbh	Measured in cm as in inventory
3.	Diameter class	Each diameter class from 10-20 to 90+ is repeated three times as the data is to be collected for three trees of same species in each diameter class.
4.	Height	Height of three different trees of same species (in m.) in each diameter class is to be recorded. The measurement of the height is to be made as is done in forest inventory.
5.	Crown length	The length of the crown of all the three trees in each diameter class is to be recorded in nearest meter.
6.	Crown width CW1 & CW2	Crown width of the tree will be measured to the nearest meter, first (CW1) towards plot centre and second (CW2) should be perpendicular.
7.	Shape of the crown	The shape of the crown of all the trees in each diameter class will be recorded as follows: **Code** **Shape** 1 Concoid 2 Paraboloid 3 Hemisphere 

8.	Blanks in canopy	Blanks in the canopy of individual tree is to be recorded in percentage of total canopy
9.	Weight of wood, twigs, leaves, flowers and fruits	This data is to be collected from only one tree in each diameter class. The data for weight of wood, twigs, leaves, flowers and fruits will be obtained by opening a window of 1 sq.m in all the four directions in the crown until woody branches of 5cm dia is reached. All such material from the window will be felled and weights of woody branches, twigs, leaves etc. will be recorded in the respective columns. 
14.	Remarks	For palm like trees two leaves will be felled from each tree in each diameter class and their weight will be recorded in leaf column and total number of leaves in such trees will be recorded under remark column.

3.1.7 The above table provides information which can be used to calculate biomass of small wood and foliage for that particular tree. The recorded small wood biomass (green) is coming from the four theoretical cuboids having breadth and thickness as 1.0 meter and length as half of crown width. Therefore, volume of four cuboids and biomass of small-wood/foliage are known. Similarly, because of crown length, crown width and shape of the crown the theoretical volume formed by the outer surface of the tree is calculated. Using these two information biomass for these two components for the tree be calculated and adjusted for canopy blank and moisture content percentage.

3.1.8 This way, the information about 20 to 30 trees of a particular species representing all dia classes would be available. Now, taking dbh as an independent variable and biomass of these trees as the dependent variable biomass equation corresponding to each speciescan be developed. Following equations were developed for dalbergia sissoo giving weight in kilograms after using dbh in meters





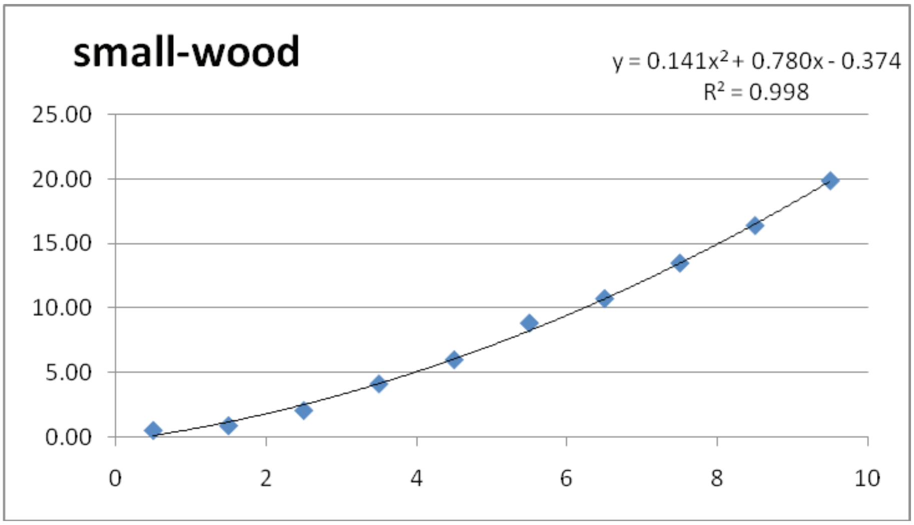
3.2.1 Biomass in small wood and foliage of trees having less than 10 cm dbh: As above, 20 important tree species in each physiographic zone were identified. The classical approach of developing biomass equation demands for destructive sampling involving felling of trees. In this case, FSI have gone for destructive sampling.

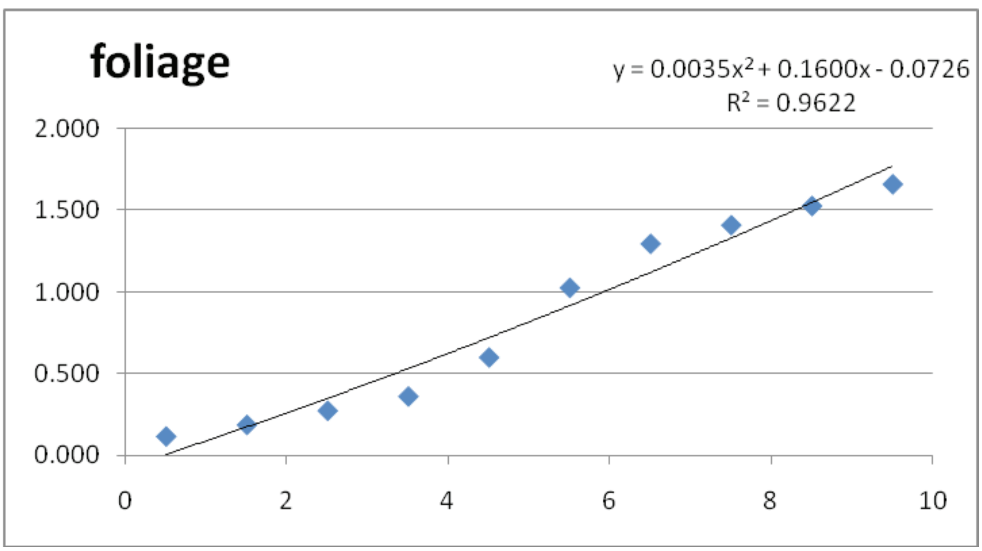
3.2.2 For each of such species, 3 trees of diameters 0- 9 cm (at 1 .37 m. height) are felled. From the felled trees, separate biomass is calculated and recorded for wood, twigs and leaves in the prescribed format. A small piece of small-wood and small amount of foliage is kept for estimating moisture percentage. On the basis of this component wise biomass is calculated for each tree.

Table1: showing the items to be recorded

1.	Species Name & Code	The name of the species for which data is being collected along with its code is to be recorded.
2.	Diameter at 1.37m	Each diameter class from 0-1 to 8-9 is repeated three times as the data is to be collected for three trees of same species in each diameter class.
3.	Weight of wood, twigs, leaves, flowers and fruits	Three trees under each diameter class from 0-1 to 8-9 are to be felled and weight of wood, twigs, leaves, flowers and fruits are to be recorded under respective columns. The diameter of each tree is to be measured at the height of 1.37m.
4.	Collar diameter(cm)	Collar diameter is to be recorded in cm up to one decimal.

3.2.3 This way, the information about 30 trees of a particular species representing all dia classes would be available. Now, taking dbh as an independent variable and biomass of these trees as the dependent variable, biomass equation corresponding to each species can be developed. Following equations were developed for Dalbergia sissoo giving weight in kilograms after using dbh in cms





3.3.1 Biomass of shrubs, herbs, climbers, dead wood and litter: For this purpose, the data of forest inventory conducted during 2002-06 was analysed for each physiographic zone to ascertain the important crop compositions and optimum number of plots required for each combination of **crop composition** and **forest density.** It reveals that about 15 plots for each combination will suffice if 30% permissible error is considered. Now, this has become part of regular inventory and the estimates will be improved continuously.

For this purpose, the information was collected from 15 selected districts from all physiographic zones representing almost all forest types of the country. These districts were already inventoried during 2002-06 and it was known point wise what was the canopy density and what was the crop composition of those points. Therefore, 15 samples from each strata were selected and, the latitude and longitude of the optimum number of plots are supplied to field parties from headquarters. Taking lat

& long as centre of sample point, **three concentric plots of size 5mx5m, 3mx3m and 1mx1m** are laid out at a distance of 30m away from the centre of sample point in North and South direction. In 5mx5m plot, all **dead wood** above 5 cm diameter is collected, weighed and recorded. In 3mx3m plot, all **woody litter** i.e. all branches below 5 cm diameter are collected, weighed and recorded. All **shrubs & climbers** in 3mx3m plots are uprooted, weighed and recorded in the prescribed format. In 1m x 1m plot, all **herbs** are uprooted, weighed and recorded. In all the three plots, the name of the dominant species is also recorded.

3.3.2 On the basis of these information, component wise biomass per unit of area was estimated. This information as factor for that particular strata.

3.4.1 In addition to above, the information on carbon stored in bamboo and bark of trees has also been estimated for each sample plot. For estimating volume of the bark, the double bark thickness of trees measured during forest inventory and volume equation of trees have been used. With the help of the specific gravity of bark, the volume was converted into biomass. Using carbon content of wood, carbon stored in bark was estimated.

3.5.1 Methodology to estimate Carbon in finished wood products: The carbon stored in the harvested wood products was estimated from the study “Production and Consumption of wood” conducted by FSI in 75 districts in the country during 2008-09. Stratified random sampling was employed for the survey. The country was stratified into 23 strata formed on the basis of large states or group of states/UTs. The districts were first stage sampling units. It was presumed that production and consumption of wood in the district is related with the per capita forest cover. Accordingly, per capita forest cover of districts was utilized to ascertain optimum number of districts (sample size) required for the study, which comes out to be 62. To get proper representation of the said 23 strata, districts within strata were arranged in two groups, one containing districts having per capita forest cover more than or equal to the average per capita forest cover of the state (strata) and other containing districts having per capita forest cover less than the average per capita forest cover of the state. It was decided to choose at least three first stage sampling units (districts) from large states (strata). In this process the ascertained sample size of 62 districts has increased to 75 which were chosen randomly. In each selected district, data on production and consumption of wood is being collected.

3.5.2 Carbon in finished wood products in Commercial units: The optimum number of registered industrial units (sample size) to be surveyed was based upon the results of the study on “Saw milling Survey” conducted by FSI during 1978-79. It was presumed that the average production of industrial units would remain, by and large, same and so is its variation. The sample size from this study was ascertained as 2300 for whole of the country. This sample size is equally distributed in all the selected 75 districts ie, 30 industrial units from each district. In a district industrial units are categorized in four groups on the basis of products it makes. 30 sampling units are proportionately allocated to different groups. In addition to data on production, inputs etc quantity of wood in usage in construction and furniture & fixtures were also recorded. Wood based industrial units which are not registered with the agency from which the list of WBI is obtained and the small establishments (Match, Packing case, Furniture, Sports goods, Wood carving, Basket making, Kattha, Mining, Brick kilns, Lime kilns, Oil & jiggery mills, Potteries & utensil making, Body building of various vehicles including boats, tool handles making, tent house, Dhaba, Pole & balli suppliers etc.) consuming wood as input for manufacturing products or as a source of energy was covered separately while surveying households.

3.5.3 Carbon in finished wood products in Households and small establishment: The sample size for estimating wood consumption in households and small establishments had been determined on the basis of "Wood Consumption study of Haryana" conducted by FSI during 1995. Using the results of this survey, it is ascertained that 100 villages and 50 UFS blocks are to be surveyed from each state/group of states/UTs for collection of consumption data on small timber, pole, bamboo and fuel wood in households and small establishments in rural and urban areas.100 villages and 50 UFS blocks will be equally distributed among all the selected district of the state. All villages of district will form rural sector and will be arranged in descending order of population. If n villages are to be selected then this list of villages will be grouped into n/2 groups and 2 villages will be randomly selected from each such group. In the selected villages/UFS blocks, the households were categorized in three groups based on their economic status. Thereafter 12 household from each village and UFS block were selected proportionally and randomly from each stratum. Villages were second stage sampling units for rural area and households were the third stage sampling units. UFS blocks were second stage sampling units and households were the third stage sampling units for urban sector. All the wood based and fuel wood based small establishments falling in the selected villages/UFS blocks were surveyed. In each selected households, apart from other information, consumption of wood in all the wood articles in use, were recorded. In small establishments, in addition to data on production, inputs etc quantity of wood used in construction and furniture & fixtures were also recorded.

Form the above data, volume of wood in finished products in industrial units, small establishment and household sectors were estimated. Since, it was difficult to know the species; a common specific gravity was used to convert volume data to biomass data and similarly common carbon content percentage was assumed to convert biomass to the total carbon stored in finished wood products.

Technical Session 10

GIS INTEGRATED SAMPLING DESIGN FOR FOREST INVENTORY IN INACCESSIBLE AREAS

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1. Introduction

1.1 Forests have acquired increasing importance in the recent past for their role not only in meeting the material requirements but also for their ecological and environmental functions. Therefore, accurate and up-to-date information on forest resources is of paramount importance for formulating policies. Some of the important parameters used for measuring forest resources are forest cover, growing stock, annual increment, species composition, biodiversity, non-timber forest products etc. Forest managers, planners and policy makers need information about availability of wood from important tree species growing inside and outside forest areas. Detailed information on distribution of timber species, volume, biomass, number of stems, regeneration status etc. within different zones and regions of the country is highly useful for effective planning.

2. History of forest inventory

2.1 With the start of scientific management of forests in India which strated in 1863, field inventory on a systematic basis started for preparation of the "Working Plans" at the divisional level. This was extended to almost entire forest area of the country and is continuing even today. Such inventories were for divisional level and for different time frame. However such inventories were not organised to generate estimates at state/national level for a given time frame. Field inventory of unexplored forest areas started after the launch of a FAO/UNDP/GOI project named as Pre-Investment Survey of Forest Resources (PISFR) in 1965 which led to the foundation of NFI

2.2 Between 1965 to 1981, Forest Inventory was confined to certain project areas for setting up wood based industries and the sampling design was adopted as per prevailing condition of areas. In 1981, National Forest Inventory (NFI) was launched with the creation of Forest Survey of India (FSI).

2.3 The country was divided into grids of 2.½' x 2.½' and Systematic sampling was followed by taking two plots of 0.1 ha in each grid. Each year only selected districts were covered due to limitation of manpower and districts/state level reports were produced. About three fourth of forested area of the country could be inventoried in 20 years.

3. Present Methodology of National Forest Inventory

3.1 The basic goal is to generate national level growing stock information on two year basis and improve the estimate in subsequent cycles. However, all the districts of the entire country would be covered only in 20 years. To overcome this fact, and to generate national level growing stock estimates on a two year cycle, the country was stratified into 14 physiographic zones according to tree species composition and other physiographic and ecological parameters. Ten percent of districts are inventoried in every cycle of 2 years.

3.2 1:50,000 scale Survey of India toposheet is divided into 36 grids of 2 ½´ x 2 ½¢. Further each grid is divided into 4 sub-grids of 1 ¼´ x 1 ¼¢ forming the basic sampling units. Two of these sub-grids are randomly selected and corresponding sub-grids in all the 2 ½´ x 2 ½¢ grids are selected to form the sample. The intersection of diagonals of such sub-grids are marked as center of plot on the map. At the center of selected subgrid a plot of 0.1 ha area is laid out in each such grid and data are collected from the plots falling in forest area only. For collecting data on soil, forest floor (humus & litter carbon), sub-plots of 1m x 1m are laid at each corner within the 0.1 ha plot. The data regarding herbs and shrubs (including regeneration) are collected from four square plots of 1m x 1m and 3m x 3m respectively. These plots are laid out at 30 meters from the centre of 0.1 ha plot in all four directions along diagonals in non-hilly area and along trails in hilly areas.

3.3 The data collected in the field is checked and entered by the zonal offices and sent to head quarter for processing. At the head quarter, the data received from the zones is again checked for inconsistencies and data is rectified before processing. Processing is carried out by using a specially designed software for different parameters such as area estimation, volume estimation, stand and stock tables, standard error estimation etc.

3.4 However, the use of the existing methodology for forest inventory is not feasible in areas which are thickly forested and with a hilly terrain without proper road network. Such areas exist in many parts of our country, especially in Eastern Himalayan region for which a separate sampling design needed to be developed. The existing national sampling design for forest inventory is based on stratified random sampling taking each physiographic zone as a strata. Since, stratified sampling permits usage of different sampling design in different strata, a separate sampling design for Eastern Himalayan physiographic zone (EHZ) was developed.

3.5 The new sampling design known as stratified cluster design for EHZ is based on remote sensing and GIS techniques and was developed keeping the following objectives in mind:

1. Reduction in time to carry out forest inventory.
2. Achievement of desired level of precision
3. Easy accessibility of sample points.

The following section highlights methodology of the new sampling design using GIS in Papumpare, West Kameng and Dibang Valley of Arunachal Pradesh as an example.

(1) Reduction in time to carry out forest inventory:

Past inventories of forest resources for different districts of Arunachal Pradesh were studied and it was found that the standard error percentage was on an average of 7% at district level which is much below the permissible error of 15% at the district level. Keeping in mind, if the permissible error is kept at ±10% level at the district level the sampling intensity can be lowered to achieve the desired level of precision. As the road network is not well spread it is presumed that, the disturbance in forest cover and area will also not be very high. If variation in forest cover for both dense and open forests at different altitudes can be captured, then cluster of sample points may provide micro level variations. Consequently, after a series of permutations & combinations it was decided that 25 clusters of five sample points in each cluster will capture the total variation of the forest resources of the district.

(2) Achievement of desired level of precision:

To achieve the desired level of precision, stratification of forest according to altitudinal zones was carried out. It is well known that different altitude zone support different tree species, which may cause variation in growing stock and these needs to be estimated. After going through the old inventories, important species were identified and information about their altitudinal preferences were collected from literature. On the basis of this information, it was found that if three altitude classes viz. 0-900m, 900-2,400m and above 2,400m, are taken into consideration then all the tree species can be appropriately estimated. Here it is worth mentioning that, there are some species like *Abies densa* which is found distributed at very high altitude zone in Eastern Himalayas (between 2700m-3900m). To capture its occurrence, if any, an altitudinal strata of above 3000m can also be prepared. However, in the present study only 3 altitudinal strata, viz. 0-900m, 900-2400m and greater than 2400m were created. In any altitude zone, variation in vegetation cover is due to slope, aspects, soil etc. resulting in dense or open formation of canopy cover and, therefore, within each altitudinal strata further stratification was done according to forest cover i.e. very dense forest (VDF), moderately dense forest (MDF) and open forest (OF). Accordingly, a total to 9 strata in different altitudinal zones and with different forest cover density were created which is depicted in a tabular form for West Kameng District:

Table 1: Area under Different Strata in West Kameng District

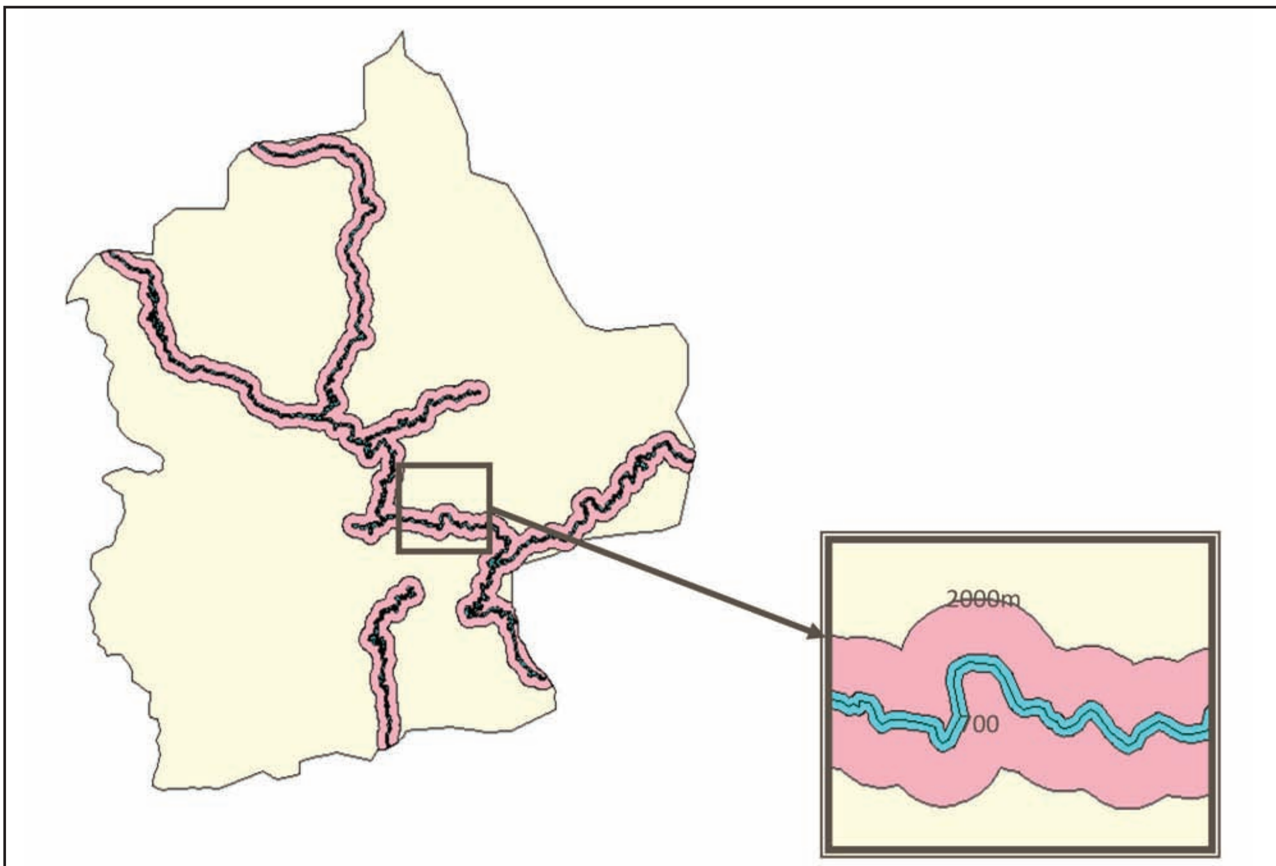
Area in ha

Altitude Zone	VDF	MDF	OF	Total
0-900	9,845	27,592	3,459	40,896
900-2400	50,725	1,44,574	37,716	2,33,015
2400 & above	30,933	74,972	33,551	1,39,456

(3) Easy accessibility of sample points:

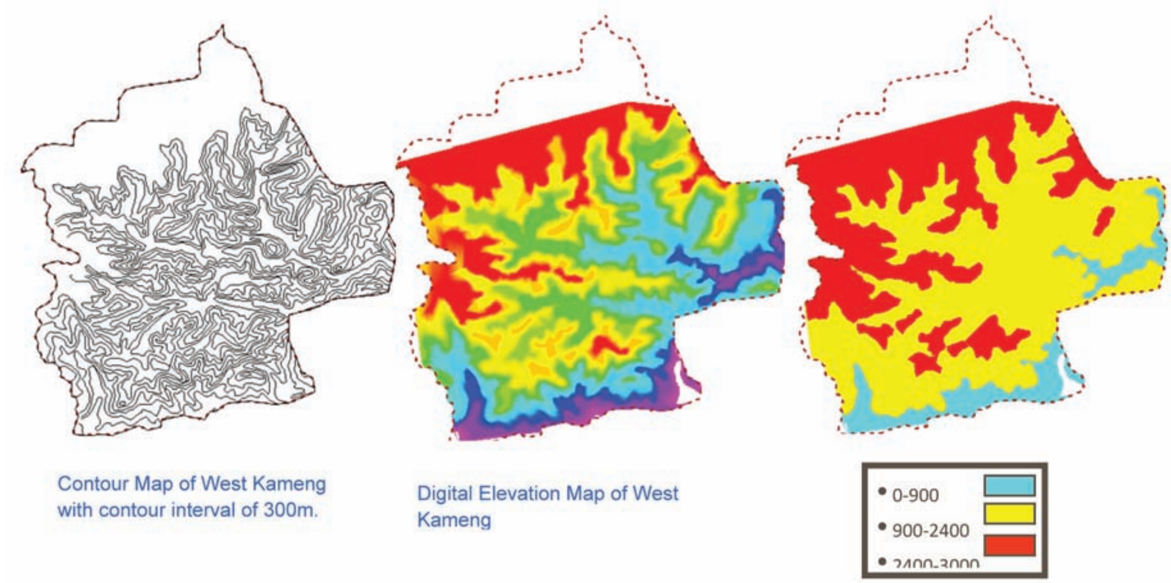
Since the road network and track network is not well spread, large number of sample points become inaccessible in Eastern Himalayas. To do away this problem, road network and established track network were digitized from the Survey of India (SOI) toposheet and road map of concerned district of Arunachal Pradesh.

A buffer of seven hundred meters from the center of the road was created deliberately with an intention to avoid this buffer from random selection as being close to road and the areawould be prone to destruction/disturbance. This is verified from the fact that the dense forest in such areas (centre of road to 700m on either side) have a canopy density of 56% as compared to 70% for the entire district. Subsequently, another buffer of 2000 meters from the center of the road was created and this buffer minus the previous buffer was considered for random selection of desired cluster points (i.e. 2000m – 700m = 1300m).



Road Network Map of West Kameng with two buffer Zones of 700m and 2000m

For randomly selecting the sample clusters, use of GIS technique was applied. Firstly, the digital elevation model was created on the basis of contours at a distance of 300m from which 3 different altitudinal zonations were created as shown below.



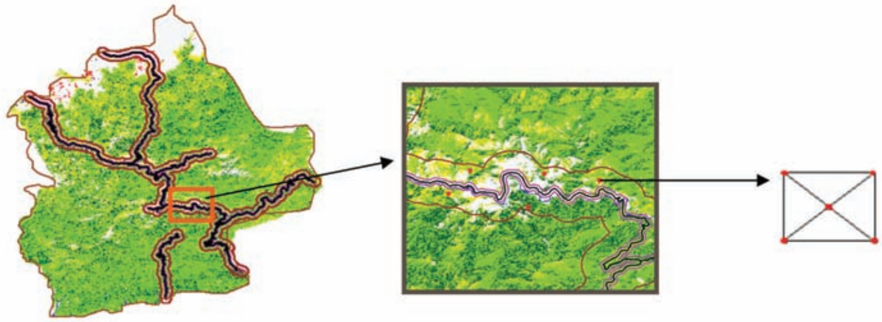
On the basis of altitude and forest cover (VDF/MDF/OF), nine strata were created. These are VDF/MDF and open with 0-900m, 900-2400m, and >2400m. Then according to the size of strata the 25 clusters were proportionately allocated to all the strata.

Table 2: Proportionate Distribution of Cluster Sampling Points

Area in ha

Altitude Zone	VDF	MDF	OF	Total
0-900	2	2	1	5
900-2400	4	6	2	12
2400 & above	2	4	2	8

Latitude and longitude of the cluster centers of the desired number of clusters were randomly generated through GIS for each stratum for field inventory. At this point, a sample plot of 0.1 ha was laid out and four other plots laid out at a distance of 200 meter from this point in all the four directions i.e. north, south, east & west. Accordingly, each cluster will have five sample plots of 0.1 ha each with associated herbs and shrubs plots.



Forest Cover Map of West Kameng

Generation of Cluster Sample Points

There is a possibility that road network may not extend to a particular altitudinal strata, in which case nearness to road/track network was considered and extra points were allocated, which were utilized if clusters were inaccessible. In each 0.1 ha plot, data pertaining to species wise and diameter classwise trees were recorded along with other parameters for estimation of growing stock. In addition, data on shrubs and herbs were also recorded from the desired sampled plots for further analysis. Thus the new sampling design fulfills all the above stated three objectives.

4. Conclusion

Remote sensing and GIS tools have been used successfully for studying the forest resources of many countries like Nepal and USA. These tools are playing an important role in stratification of area for laying of sample plots, particularly in hilly and mountainous region, where conventional method is not yielding the desired results. In India, this methodology using remote sensing and GIS have been successfully used for carrying out sampling in Eastern Himalayan Physiographic Zone, which is very hilly and thickly forested. The results obtained for the districts in Arunachal Pradesh where this new technique was applied shows a standard error of only 4% substantiating the efficacy of the new sampling design.

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Technical Session 11

MEASUREMENT & ESTIMATION OF FORESTS CARBON STOCK DATA ENTRY AND PROCESSING

N.K.Bhatia,
H.K.Tripathi,
P.Somasundaram

1. Introduction

1.1 India has a vast experience of conducting forest inventory. The main objective of Forest Inventory is to collect qualitative & quantitative information about the forest resources within certain precision limits in preparing reports on potential and other forest based investigations for development planning. Further, from the estimates of growing stock of trees, bamboo and other parameters of special studies, forest biomass and carbon stock has also been estimated at district/ state/ country level.

1.2 Regular mandatory inventory surveys conducted by FSI are Forest Inventory and Trees outside Forests (TOF) (Rural and Urban). Besides some special studies have also been conducted by FSI which are:

I. Industrial investigation
II. Vegetational mapping etc.
III. Production & Consumption study and
IV. Biomass study

2. Forest Inventory

2.1 In Forest Inventory, about 40 key parameters/data such as Legal Status, Land use class, Terrain, Soil, Crop, Bamboo, Forest degradation, Tree height, Diameter, Bark thickness, Crown width, Soil and Forest floor, Herbs, Shrubs, Regeneration, Dead tree etc. are recorded in prescribed formats. In Forest Inventory, overall intensity of the survey comes to nearly 0.01% (actual plot data of 0.1ha represents about 10 Km.Sq area).

3. Sampling Design

3.1 The sampling design adopted for national forest inventory is two stages. In the first stage, the country is divided into homogenous strata, based on physiography, climate and vegetation called as physiographic zone and the civil districts form the sampling unit. There are 14 physiographic zones. A sample of 10% district (about 60 districts) distributed over all the physiographic zones in proportion to their size are selected randomly for detailed inventory of forest in first stage. In the second stage, selected districts are divided into grids of latitude and longitudes which form the second stage sampling unit. Systematic sampling is followed to conduct inventory in these grids. Plots are systematically laid out in the forest area which is indicated on the topography sheets of scale 1:50,000. For each selected district, Survey of India (SOI) toposheets of 1:50,000 scale (size 15' X 15' i.e. 15 minutes latitudes and 15 minutes longitude) is divided into 36 grids of 2½¢ X 2½¢ which is further divided into sub grids of 1¼¢×1¼¢ forming the basic sampling frame. Two of these sub grids are then randomly selected to lay out the sample plots. Other forested sub grids in the districts are selected systematically taking first two sub grids as random start. The intersection of diagonals of such sub grids are marked as the centre of the plot at which a square sample plot of 0.1 ha area is laid out on ground to record the measurement.

4. Formats (Field forms) for data collection

4.1 Forest Inventory data is collected and recorded in the following field forms:

I. Plot Approach Form(PAF)
II. Plot Description Form (PDF)
III. Plot Enumeration Form(PEF)
IV. Sample Tree Form (STF)
V. Bamboo Clump Analysis Form (BEF)
VI. Bamboo Enumeration and Analysis Form (non-clump forming)
VII. Bamboo Weight Form (BWF)
VIII. Herbs/ Shrubs/ Regeneration Form
IX. Soil and Forest floor Carbon study Form
X. Form B-1: Data for estimation of biomass of Shrubs, Herbs and Dead Wood
XI. Form B-2: Data for estimation of biomass of Trees below 10 cm diameter
XII. Form B-3: Data for estimation of biomass of Branches, Foliage etc. for trees above 10cm diameter.

5. Data Entry

5.1 After data has been recorded in the prescribed field forms, following tasks are to be carried out in the concerned Zonal offices of FSI.

I. Coding of information in the field form (for example, Job no. etc.)
II. Entering the field form's coded data information in computer through data entry modules which have already been developed using VB. Net & MS Access.
III. Sending of Forest Floor/Soils samples to laboratory for analysis purpose.
IV. Filling up of obtained analyzed results in the field forms.
V. Sending the entered data information in CD to head quarters for checking and processing.

6. Data checking and cleaning

6.1 Before processing begins, data collected from field has to be cleaned. Data cleaning involves the following steps:

I. Listing of loaded data is taken.
II. Checking of field data for possible inconsistencies.
III. Incorporation of the corrections/reconciliation of data discrepancies in consultation with the zonal officials/officers.

7. Validity checks to be applied on data

7.1 To make the data more relevant and usable, certain validity checks,(though data entry module itself takes care of it), are applied on the entered data. These are:

I. **Width check:** Numeric data should be filled up with required left hand zero(s). For example, if width of land use code is 2, the same should be filled in two digits only, i.e., open forest is to be coded as 04 and not 4. Required command for this check are already in the data entry

II. **Range check:** It is to check whether data recorded is in prescribed range. For example, if land use code ranges between 01 and 16, any numeric other than this is an error which needs to be corrected. Data entry module takes care of such discrepancies and does not allow out of range digits.

III. **Logical checks:** This is required to check the data logically. Actually, there are some parameters in the plot description form which are directly related to each other. Data entry module takes care of such checks.

8. Validity and Consistency checks to be applied on PDF data

i. Land use:

(1) All the field forms are to be filled up when land use code is 01, 02, 03, 04 and 07.

(2) There is no separate code for pure bamboo. However, depending upon the occurrence of the bamboo i,e, if the bamboo density code in PDF is 1 or 2 ,then land use code will be 01, if bamboo density code is 3 or 4 then land use code will be 02 and when bamboo density code is 5 or 6 in PDF, land use code is to be recorded as 03. In all the three cases, crop composition should be 12, 22 or 23.

ii. Slope:

(1) Slope when converted to percentage should be exactly the same as given in the slope percentage annexure.

(2) If general topography code is 1 (Flat), Slope % should be less than 006 ($\leq 3^o$).

iii. Position on slope: If general topography code is 1, then this code should be 6.

iv. Aspect: If general topography code is 1, this code should be 9.

v. Soil Texture:

(1) If soil consistency code is 1, this code should be 4 or 5

(2) If soil consistency code is 2, this code should be 2 or 3

(3) If soil consistency code is 3, soil texture is to be recorded as 1 or 2.

(4) If soil consistency code is 4 then soil texture should be 1

(5) If the soil consistency code is 5, soil texture should be recorded as 6.

vi. Crop composition:

(1) This two digit code is to be filled up when land use code is 01, 02, 03, 04 or 07.

(2) This code will not be filled up when land use code is from 11 to 16.

(3) This code should be 12, 22 or 23 when plot has pure bamboo.

vii. Canopy layer:

(1) If land use code is 06 or from 09 to16, then canopy layer is to be left blank.
(2) If land use code is 07, then this code should be recorded as 1.

viii. Size class:

(1) If land use code is 07 then size class should be 1.

ix. Bamboo data:

In PDF, if Bamboo density code is 8, bamboo quality code will be 5, bamboo flowering code will be 4 and bamboo regeneration code will be 5. If Bamboo density code is 9, bamboo quality code will be 4. Bamboo quality code given in the BEF should be same as given in the PDF.

x. Plantation potential:

(1) If land use code is 01, 02, 09 or 12-16 then plantation potential code should be 3.
(2) If land use code is 03, 04, 06, 08, 10, 11, then plantation potential code should be 1 or 2.
(3) If land use code is 07 or 01-03 (with crop composition 12) then any code from 1 to 3 may be assigned to plantation potential.

xi. Plot status:

(1) If plot status code is 1, all the columns of the PDF are to be filled. If it is 2, all the columns of PDF except regeneration data are to be filled.
(2) If plot status code is 3, all the columns of the PDF except regeneration and slope data are to be filled.
(3) If plot status code is 4 then all the columns up to the legal status parameter are to be filled. If possible, also fill crop composition.

9. Validity and Consistency checks to be applied on PEF data

I. Total number of bamboo clumps / trees given in column72-74 and in column 75-77 respectively should be sum of bamboo clumps / trees appearing in the PEF.
II. Mapsheet number and grid code given in this form should be same as given in PDF.
III. All the bamboo clumps enumerated should be numbered as 1, 2, 3,……….

10. Validity and Consistency checks to be applied on STF data

I. Map sheet number and grid number should be same as given in the PDF
II. Species code and diameter of all the trees in this form should be exactly the same as given in PEF.
III. While recording dominance, due care is to be given to the fact that higher is the tree, lower is the dominance code.

11. Validity and Consistency checks to be applied on BEF data

I. Map sheet number and grid number should be same as given in the PDF

II. Bamboo quality given in this form should be same as given in the PDF.
III. Bamboo clumps in this form should be at serial number 1, 9, 17, 25.... of PEF.

Note:
"Herbs/ Shrubs/ Regeneration Form" and "Soil and Forest floor Carbon study Form" are to be filled irrespective of the land-use codes except barren lands and water bodies.

12. Validity and logical checks to be applied on regeneration data

I. Parameters "Intensity of Regeneration" and "Species under Regeneration" are linked together. If Intensity of Regeneration code is 1 or 2, codes of dominant species under regeneration should be given but if regeneration intensity code is 3 (Absent), regeneration species code should be left blank.

II. Parameters "Intensity of Regeneration" in "PDF" and "Category of Regeneration" in "Regeneration Form" are also linked. Total number of plants having dbh less than 5 cm (whether established or recruit) and plants with dbh 5 & less than 10 cm will decide the Intensity of Regeneration code. If total no of plants recorded in "Regeneration Form" is ≥ 18, then Intensity of regeneration code will be 1. If total no of plants recorded in "Regeneration Form" is < 18, then Intensity of regeneration code in PDF will be 2. Otherwise, Intensity of regeneration code will be 3. Again for regeneration plants with dbh 5 cm or more, category code is not to be filled up.

III. Species under regeneration recorded in PDF is the species which occurs maximum in the "Regeneration Form".

13. Validity checks to be applied on Soil/ Forests Floor Data

I. Gravel proportion percentage and soil proportion percentage when added together should not exceed 100.

II. Forest floor weight is to be collected from only two corners namely NE and SW quadrants. The weight data is to be recorded in grams and in 4 digits (weight 60 gm to be recorded as 0060, 3kg as 3000, 2kg 60 gm as 2060).

14. Processing of Data

14.1 Finally, when data is cleaned after reconciliation of discrepancies, processing is done using various modules which have been developed by FSI in Visual Basic as front end and MS Access as back end.

14.2 Main processing involves:

I. Estimation of growing stand and stock of wood
II. Bamboo growing stock estimates
III. Soil/Forest Floor Carbon estimation
IV. Regeneration data analysis
V. Herbs, Shrubs, climbers, dead wood study
VI. Estimation of Carbon

15. Estimation of growing stand and stock of wood

15.1 Whole estimation process involves the following steps:

I. Distribution of data of different parameters (2 and 3 ways tables).
II. Distribution of area of different parameters of the PDF.
III. Distribution of total inventory area into tree vegetated area, less vegetated area
and area not supporting tree vegetation.
IV. Calculation of the per plot area.
V. Calculation of the per plot volume.
VI. Estimation of the enumerated stems and their volume.
VII. Estimation of the enumerated stem per ha and volume per ha.
VIII. Estimation of the total stand and stock , per ha stand and stock for district level.
IX. Standard error percentage calculation.
X. Statistical analysis of the obtained result.

16. Volume Equations

16.1 Volume of trees can be obtained using volume equations. FSI is enriched with about 800 volume equations of around 200 timber species of India which are developed by FSI itself. Volume equations are of two types; Local Volume Equations & General Volume Equations.

In Local volume Equation, (L.V.E)
V=f (D) where D is overbark DBH
and in General Volume Equations, (G.V.E)
V= f (D, H) where d is over bark DBH & H is height of tree in m.
For example, for Shorea Robusta (Sal) growing in Ranchi district,
G.V.E is $V/D^2H = 0.0041834/ D^2 H+0.37802$ and
L.V.E is $V/ D^2 = 0.022585/ D^2 - 0.70158/D+8.714$

17. Biomass Equations

17.1 Biomass of (i) Stems of diameter below 10cm & branches of diameter below 5cm of Trees having diameter 10 cm and above (ii) foliage (includes leaves, green twigs, fruits and flowers of trees of diameter 10cm and above (iii) Small woods of Trees having Diameter below 10 cm and (iv) foliage (which includes leaves, green twigs, fruits and flowers) of Trees having Diameter below 10 cm are estimated using Biomass equations developed from special study data.

For example,
Biomass equations developed for the Ficus species are

(i) Biomass = 359.1*D - 12.92 (for biomass of Stems of diameter below 10cm & branches of diameter below 5cm of Trees having diameter 10 cm and above)
(ii) Biomass = 57.97*D - 3.646 (for biomass of foliage of trees of diameter 10cm and above)

(iii) Biomass = 0.141*(D^2) - 0.180*D + 0.410 (for biomass of Small woods of Trees having Diameter below 10 cm)

(iv) Biomass = 0.010*(D^2) + 0.026*D + 0.011 (for biomass of foliage of Trees having Diameter below 10 cm)

In these equations D is in meter and Biomass is in kgs.

18. Procedure for estimating Carbon Content in the Trees with Diameter 10 cm and above

Information Collected:

Information about species name, code and its diameter is collected in PEF.

I. Carbon content in Stems of diameter 10cm and above & branches of diameter 5cm and above:

i) Under bark volume (in cu.m) of each tree is calculated using volume equation.

ii) This volume is multiplied with specific gravity of that species to get woody biomass (in tonnes).

iii) Finally carbon content in this category is obtained by the following formula

Carbon content of wood = Biomass x Carbon Content percentage.

iv) The individual tree carbon content is added to get the plot carbon contents.

v) Then per hectare carbon content is obtained using the formula

$$\text{Per hectare carbon content} = \frac{\text{Total CC in 'n' places}}{n} \times 10$$

vi) This per hectare multiplied by the area gives the estimated carbon content of wood in that area.

II. Carbon content in Stems of diameter below 10cm & branches of diameter below 5cm:

i) Biomass equations developed for important species to get the biomass of stems of diameter below 10 cm & branches of diameter below 5 cm after conducting a special study.

ii) Using these biomass equations, biomass of each tree is estimated.

iii) Finally carbon content in this category is obtained by the following formula

Carbon content of wood = Biomass x Carbon Content percentage.

iv) The individual tree carbon content is added to get the plot carbon contents.

v) Then per hectare carbon content is obtained using the formula

$$\text{Per hectare carbon content} = \frac{\text{Total CC in 'n' pots}}{n} \quad \text{Per hectare carbon content} = \frac{\text{Total CC in 'n' pots}}{n} \times 10$$

This per hectare multiplied by the area gives the estimated carbon content of wood in that area.

III. Carbon Content in foliage of trees of diameter 10cm and above (includes leaves, green twigs, fruits and flowers):
Same as given above in para **II.**

IV. Carbon Content in Bark

i) From sample tree form regression equations are developed to estimate double bark thickness (DBT) of the trees.
ii) DBT is added to diameter at breast height (DBH) and volume is calculated using volume equations with over bark diameter to get the over bark volume.
iii) Then bark volume is obtained by the formula
Bark volume = (Over bark volume – under bark volume) X (1 – void factor)
iv) Bark Biomass (in tonnes) is obtained from the formula :
Bark Biomass = bark volume X specific gravity of bark.
v) Carbon Content (in tonnes) is obtained using formula
Carbon Content bark = Bark Biomass X Carbon Content percentage.
vi) Total estimation of carbon contents in bark is obtained by the procedure shown above

Thus Total carbon content of trees above 10cm diameter is obtained by adding all the above estimated components.

19. Procedure for estimating Carbon Content in Bamboo

The whole processing for this purpose mainly evolves:

I. Distribution of bamboo area by density class.
II. Distribution of bamboo area by quality class.
III. Distribution of bamboo clumps by quality and size class.
IV. Distribution of bamboo clumps per ha by bamboo quality and size class.
V. Distribution of bamboo bearing area by quality and density class.
VI. Distribution of bamboo culms /clumps by age, quality and size class.
VII. Mean number of bamboo culms /clumps by age, soundness of culms, quality and size class.
VIII. Mean number of bamboo culms per ha by age, soundness of culms, quality and size class.
IX. Total no. of bamboo culms in the bamboo area by quality and size class.
X. Estimation of green bamboo stock by soundness of culms quality and size class.
XI. Estimation of dry bamboo stock by soundness of culms quality and size class.
XII. Carbon estimates are generated by multiplying dry bamboo stock by carbon content percentage.

20. Procedure for estimating Carbon Content in the Trees with Diameter below 10 cm

20.1 This category includes all plants having diameter between 4 cm and 10 cm diameter, established plants(plants having height more than 2m and diameter < 5cm), un established plants (plants having height < 2m and diameter < 5cm and more than one year old which includes whippy and sub whippy plants) and Recruits (very small plants having 2-4 leaves but are current year seedlings).

20.2 Information Collected:

Species name, code, diameter of trees having diameter between 4 cm and 10 cm diameter and species name, code and category of regeneration for plants having diameter less than 5cm in "Regeneration Form".

20.3 Estimation Procedure:

20.3.1 Biomass equations are established with diameter as independent variable from special study. These equations are developed for 15-20 important species in each physiographic zone. Two sets of BME's are developed. One for estimating wood Biomass in these plants and another for estimating leaf biomass, which includes leaves, green twigs, fruits and flowers.

20.3.2 Woody Biomass of plants having diameter > 4 cm, Established plants and unestablished plants are estimated by putting exact diameter, 3.5 cm and 1.5 cm respectively in the woody biomass equation and then biomass so obtained is multiplied with carbon content percentage (small wood) for less than 10 cm diameter to get carbon content in the woods of these plants.

20.3.3 Foliage biomass of plants having diameter > 4 cm, established plants, unestablished plants and recruits are estimated by putting exact diameter, 3.5 cm, 1.5 cm and 0.5 cm respectively in the leaf biomass equation and then this biomass so obtained is multiplied with carbon content percentage (leaf) for less than 10 cm diameter to get carbon content in foliage of these plants.

20.3.4 The individual plant carbon content is added to get the plot carbon contents. Then per hectare carbon content is obtained using the formula

$$\text{Per hectare carbon content} = \frac{\text{Total CC in 'n' pots}}{n} \quad \text{Per hectare carbon content} = \frac{\text{Total CC in 'n' pots}}{n} \times 10$$

This per hectare multiplied by the area gives the estimated carbon content of plants of diameter less than 10 cm in that area.

21. Procedure for estimating Carbon Content in the Dead Wood, Litter, Shrubs, Climbers and Herbs

I **Dead Wood:** Woody material of the tree having diameter more than 5 cm which is not part of a live tree, lying on the ground. This data is collected from 2 square plots of dimensions 5m X 5m in the NE & SW directions.

Information available

i. Presence of dead wood is recorded which is categorized in 4 classes; Sporadic, medium, gregarious and absent.

ii. If dead wood tree is large, its species name and diameter at breast height (in cm) is to be recorded, otherwise weight of dead wood to be recorded in Kg.

Estimation Procedure

i. Land use and crop composition wise number of plots surveyed is listed.
ii. Land use and crop composition wise enumerated dead wood weight (in kg) is listed.
iii. Land use and crop composition wise average per plot wt. is calculated Average dead wood wt./ha = Avg. dead wood wt(kg) x 10000)/(2 x 25).
iv. Physiographic zone level estimations are obtained by multiplying area with per hectare figures.

II **Litter:** Woody material of the tree having diameter less than 5cm which is not decomposed. This data is collected from two square plots of dimension 3m X 3m in NE & SW directions.

Information collected

i. Weight of litter (branches) is recorded in Kgs.
ii. Only branches with less than 5 cm diameter and which are not decomposed to be collected.

Estimation Procedure

i. Land use and crop composition wise number of plots surveyed is listed.
ii. Land use and crop composition wise enumerated litter weight (in Kgs) is listed.
iii. Land use and crop composition wise average litter weight is calculated.
iv. Land use and crop composition wise average litter weight per hectare = (Average litter weight X 10000) / (2 X 9).
v. Physiographic zone level weight of litter is obtained by multiplying area with per hectare figures.

III **Shrubs:** Usually not exceeding 3m in height with woody stem. Procedure for the estimation of shrubs is same as explained above for litter.

IV **Climbers:** Estimation procedure is same as explained above.

V **Herbs:** Not exceeding 1m in height with soft stem. Data is collected from 2 square sub plots of 1m x 1m in NE and SW directions at a distance of 30m from plot center.

Information Collected weight (in gms) of herbs after uprooting all the plants in the respective plot is recorded and the name of the dominant species of herbs is also to be recorded.
Estimation Procedure for the estimation of herbs is same as explained above for litter.

22. Procedure for estimating Carbon Content in Soil and Forest Floor Soil

Information collected: Information on soil about proportional of gravel and soil, weight of dry soil and soil organic carbon content is collected in “Soil and Forest floor Carbon study Form”.

Estimation Procedure:

Standard average wt of dry soil per hectare	=A kgs
(For example, from FRI literature, it is 4 million kgs)	
Therefore, wt of dry soil in 0.1 ha plot	= (A/10) kgs
Proportion of soil in the sampled plot	=B %
Therefore, wt of dry soil in the sample plot	= (B/100)*(A/10) kgs
Soil organic carbon content in the sample plot	=C% (% of dry matter)
Therefore, totals CC in the soil of the sampled plot	= (C/100)*(B/100)*(A/10)
	=A*B*C/100000 kgs.

II **Forest Floor:** It is data of fresh, partially and fully decomposed leaves, twigs and branches which is present on the uppermost surface of soil in form of humus.
Information collected: Information on forest floor about weight, dry weight and organic carbon content is collected in "Soil and Forest floor Carbon study Form".

Estimation Procedure:

Sampled area	= 2*(1m*1m) =2 Sq m
Weight of Forest floor in the sampled area	=X kgs.
(Sum of weight of FF in the 2 quadrants)	
Dry weight of Forest Floor in the sampled area	=Y %
Dry weight of forest Floor in the sampled area of 2 sq m	=(Y/100)*X Kgs
	=X*Y/100 Kgs
Dry weight of Forest Floor in 0.1 ha plot	=(X*Y/100)*(1/2)*1000 Kgs
	=5*X*Y Kgs
Forest Floor organic carbon content in sampled area	=Z% (On % of dry weight)
Total CC in the forest Floor of the 0.1 ha plot	= (Z/100)*(5*X*y) Kgs
	=(X*Y*Z/20) Kgs

Technical Session 12

APPROACH FOR SYNTHESIS AND LIMITATIONS

Mr. Rajesh Kumar
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Forest Survey of India

1. Introduction

The estimation of forest carbon is a complex issue as it encompass number of concepts like tier, approaches, carbon pools etc; number of definitions like forest, volume, specific gravity, moisture content, etc; number of methodologies like remote sensing based, GIS based, field survey based, etc; number of components like woody biomass, foliage biomass, bark biomass, etc. All of these give rise to different numbers (estimates) for different pools in different strata. All of these numbers are to combined to provide single set of numbers for the entire forest sector. As discussed earlier any national reporting has to conclude whether the sector is emitting to or removing carbon from the atmosphere. Let us revisit every aspect through an example.

2. Data Improvement

The current journey aims to completeness of the data and improvement of the accuracy level to follow Tier 2 or Tier 3 Level of IPCC good practice guidance for LULUCF using specific data of sub-national level. For this purpose, FSI under took a special nationwide study since August 2008 on missing components of forest biomass for generating country specific information.

3. The input used in the methodology

1. Latest forest cover (of years 2005),
2. forest type area data analyzed by remote sensing,
3. Recent growing stock data obtained from National Forest Inventory done during 2002-2006,
4. Bamboo biomass through NFI,
5. Bark
6. Soil organic carbon data obtained from NFI
7. Biomass data of missing components (smallwood, branchwood, deadwood, litter, shrub, herb and foliage) analyzed from 2008-09 study.
8. IPCC default values for below ground biomass

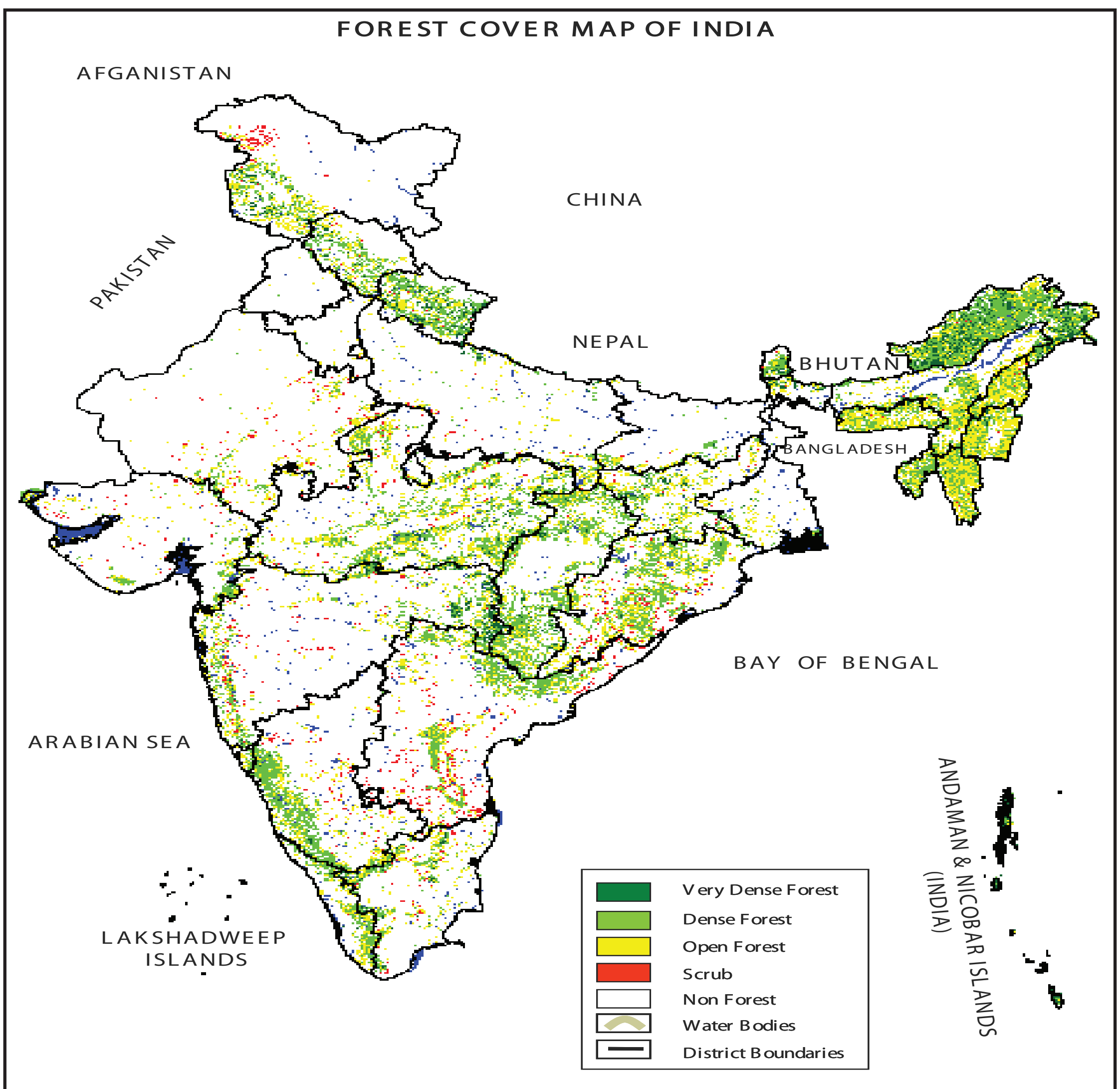
4. Input Generation

Most of the input used for estimating the forest carbon stock has been generated at the FSI. The specific gravity for determining the biomass and factors for converting biomass into carbon has however, been taken from published papers from FRI and other research institutes in addition to IPCC default values.

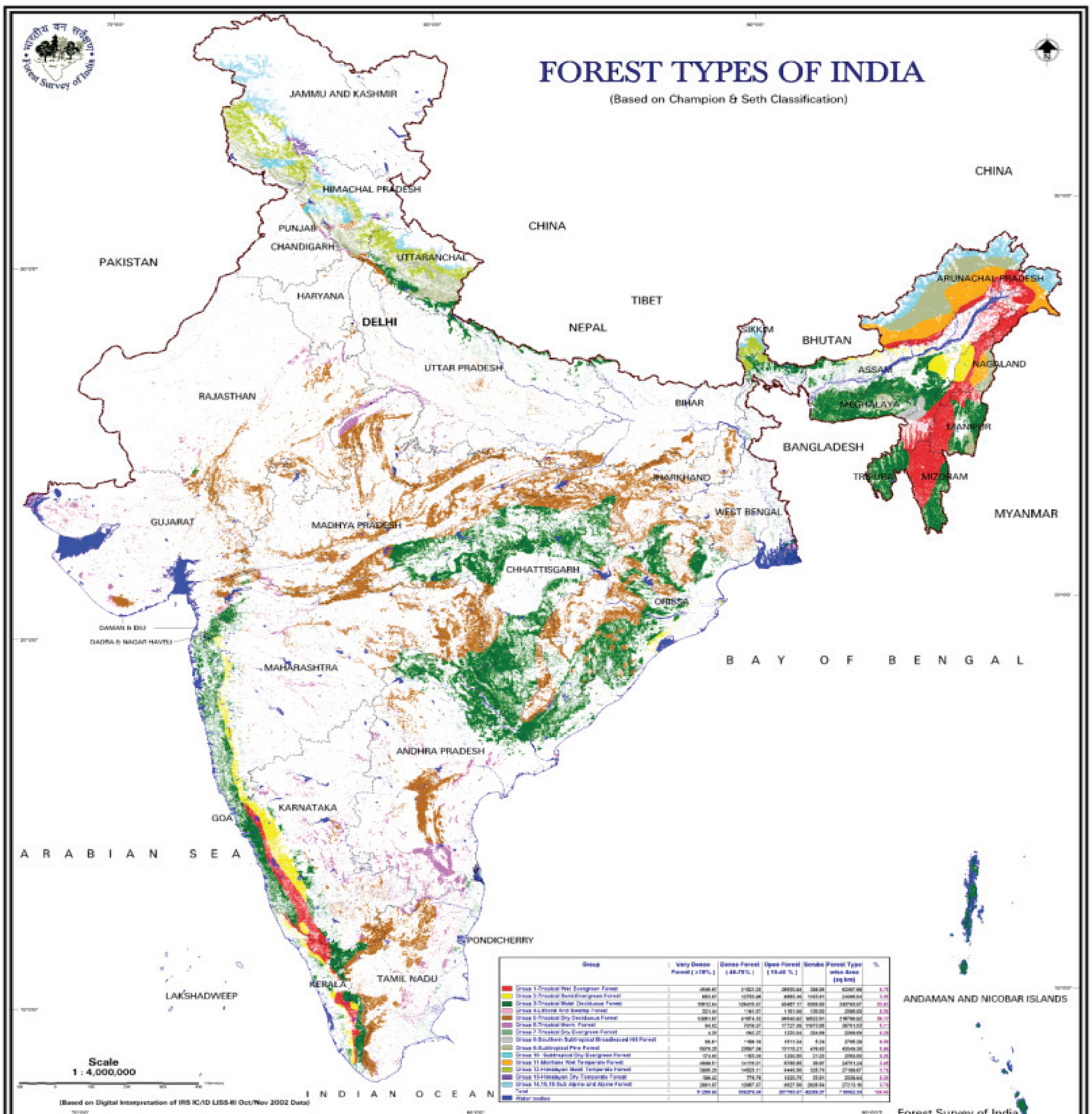
5. Assessment of 'Activity data

Activity data, ie aerial extent of forest is ascertained through satellite data. Forest cover information is stratified using canopy density and forest type variables. There are three canopy density classes and 15 type groups and therefore in all **45 such strata**.

5.1 Forest cover: FSI has been assessing the forest cover of the country on a two year cycle using remote sensing technology since 1987. Over the years there has been improvement in the technology and methodology of interpretation. Since 2001 the satellite imagery of 23.5 m resolution is digitally interpreted on 1:50,000 scale, allowing for a more objective and accurate assessment of the forest area and the changes. In the assessment three classes are made based on the canopy densities; very dense forests (more than 70% density), moderately dense forests (density between 40 to 70%) and open forests (density between 10 to 40%). The change analysis is carried out using the results of the preceding cycle which provides shift of area from one to other class within forest as well as between forest and non-forest.



5.2. Forest Type Mapping: Forest type wise extent of forest cover is useful information which provides a basis for characterizing forests in terms of floristic composition and ecological value. Recently, FSI has done mapping of forest types of India, according to Champion & Seth classification (1968) on 1:50,000 scale down up to 200 types described in the classification. In the first ever such attempt at the national level, extensive study in GIS framework using the relevant layers like, soil, rainfall, temperature along with the remote sensing data, details from the working plans, thematic maps of FSI, inventory information etc were carried out. The exercise involved extensive and widespread ground truthing covering every part of the country. The district wise forest type maps of the entire country have been prepared. Using the forest type maps, distribution of forest cover in different forest types has been determined for the country.



5.3 The activity data comes in the form of areal extent in case of LULUCF sector, following table provide such information about Uttrakhand state of India.

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

6. Emission factors

6.1 Further, FSI has been conducting national forest inventory since 2002 following a stratified and systematic sampling approach in which about 3,500 sample plots of size 0.1 ha are laid in the forests every year distributed throughout the country and several measurements on trees (above 10 cm diameter only) and forest floor are recorded. About 21,000 plots have been laid during 2002-2008. These data have been analyzed using volume equations developed for different tree species to estimate the growing stock (woody volume of trees) of forest. The growing stock of India's forest has been estimated as 5,129 million m^3.

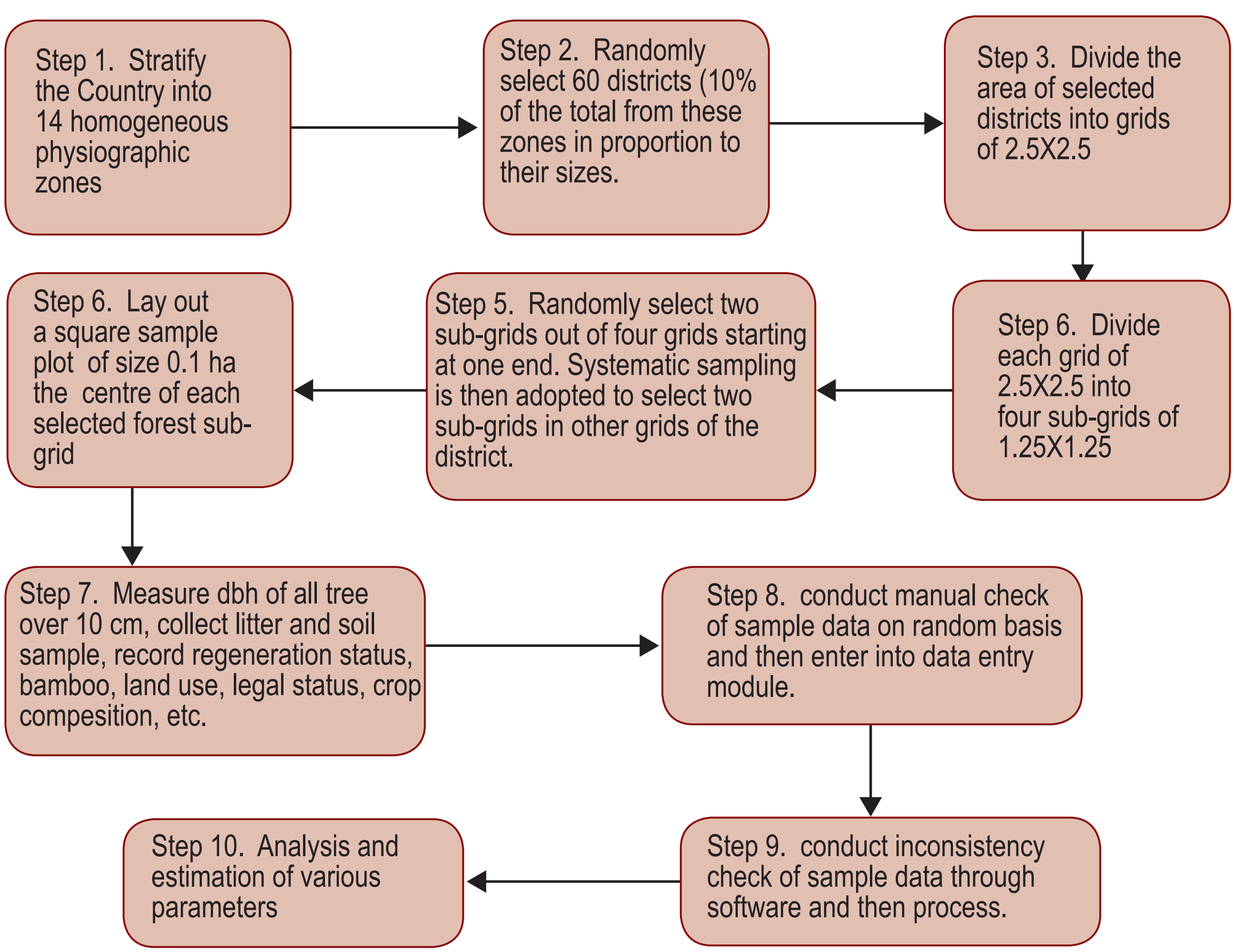
6.2 During field inventory soil sample is also collected by digging pits of $(30cm)^3$ at the center of the sub-plots for analyzing soil organic carbon. The humus and small litter is also collected from this sub-plot and analysed for organic matter content. The estimates of bamboo biomass and carbon stocked in this resource are also calculated from NFI data. Species-wise dbh and barkthikness equation are developed which are utilized to develop bark volume, biomass and carbon stored therein.

6.3 The current national forest inventory does not measure the total biomass of the trees (tree below10 cm and branch wood), besides not measuring the biomass of herbs and shrubs, deadwood. Therefore, a separate exercise has been undertaken to estimate the biomass of missing components.

6.4 In the nationwide exercise which started in August 2008, 1,400 sample plots were laid in different physiographic zones, to measure biomass of herb, shrub, climbers and deadwood and carbon in litter. Concentric plots of smaller size were laid in the selected NFI plots and samples were collected and analyzed. For estimating the biomass of small wood from trees below 10 cm and of branches and foliage about 100 predominant tree species distributed in different physiographic zones were selected. Trees below 10 cm diameters were cut from the ground and the biomass measured. For trees above 10 cm the branches were cut in a specified manner and the biomass measured. More than 200 new biomass equations have been developed to estimate the biomass of small wood.

6.5 IPCC default values for estimating the belowground biomass are available for different forest types as percentage/ratio of above ground biomass. Since the area of forests by type is now known, the appropriate default values (ranging 0.22 to 0.42) may be used to estimate the below ground biomass.

Schemaric diagram of the National Forest Inventory(NFI) in India



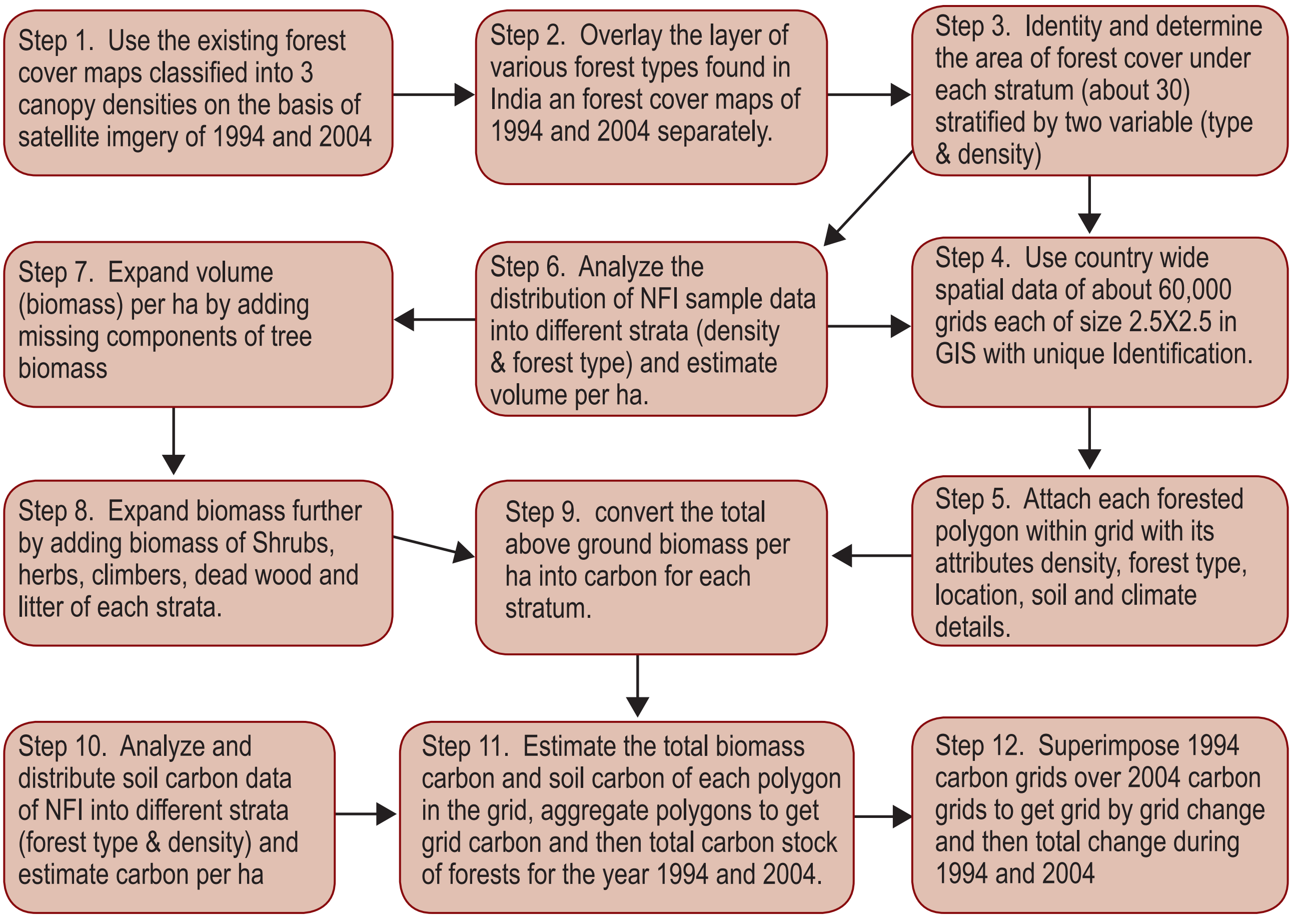
6.6 With the help of the information generated as above, following table can be prepared.

	Components	Biomass in million tonnes	Carbon in million tonnes
A.	**Above Grounds**		
A1	Woody biomass of tress above 10 cm dbh (includes stem upto 10 cm dia and branches upto 5 cm dia)	3400	1562
A2	Other Woody Biomass of the trees above 10 cm dbh (includes stem part less than 10 cm dia and branch part less than 5 cm)	648	298
A3	Woody biomass of tress below 10 cm dbh (includes complete stems as well as branches)	448	206
A4	Biomass of Bark	?	?
A5	Biomass of foliage of trees above 10 cm dbh (includes leaves, green twigs, fruits and flowers)	19	9
A6	Biomass of foliage of trees below 10 cm dbh (includes leaves, green twigs, fruits and flowers)	34	16
A7	Biomass of bamboo		
A8	Biomass of shrubs	150	55
A9	Biomass climbers	47	18
A10	Biomass herbs	38	9
A	**Total above ground (A1+A2+A3+A4+A5+A6+A7+A8+A9 +A10)**	**4785**	**2173**
B	Below ground	1509	685
T1	Total live biomass (A+B)	6294	2859
C	Deadwood	31	14
D	Litter	385	162
T	Total dead biomass (C+D)	461	176
E	Soil Organic Carbon	-	4292
	Grand total (T1+T2+E)	**6709**	**7328**

7. Reporting Carbon Stock Change

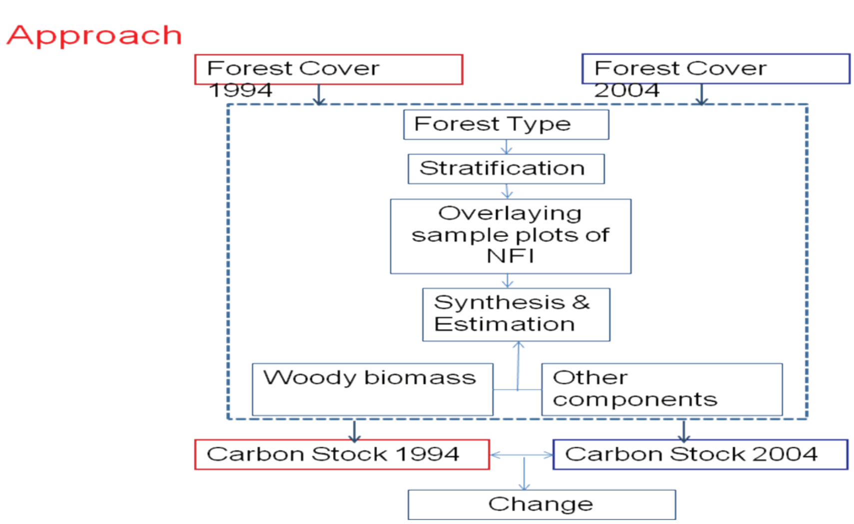
As pointed out earlier, for any international reporting, information of carbon stock in different pools for the two categories of LULUCF would be required. For this purpose activity data of two periods will be required. The following diagram elaborates the steps.

Schemaric diagram of Estmation of Carbon stock change in India's Forests



8. Approach for Estimating Carbon Stock Change

In nut shell the approach may be very well depicted from the following diagram.



8.1 The final 2 table will be of the form

Table A Change in carbon stock from **forest land remaining forest land**

Component	C Stock in 1994 (million tons)	C Stock in 2004 (million tons)	Net Change (million tons)
Above Ground biomass	2729	3409	681
Below ground biomass	861	1075	215
Dead wood	19	25	7
Litter	241	311	70
Soil	4435	4574	139
Total	**8284**	**9395**	**1112**

Table B Estimate of carbon from land converted to forest land in 2004

Component	C Stock in 2004 (million tons)
Above Ground biomass	192
Below ground biomass	61
Dead wood	1
Litter	18
Soil	258
Total	**529**

Common Data Collection Format (Draft)

Field Form No. 1 PLOT APPROACH FORM

1) Plot Approach Form must be filled in while the journey is in progress
2) While recording date it is essential to record month and year also.

1. FSI Zone
2. Physiographic Zone
3. State and Code
4. Division and Code
5. District and Code
6. Mapsheet No.
7. Grid Code
8. Crew Leader (name)
9. Name of Camp
10. Time (hrs.) at which left the camp
11. Distance covered by vehicle (km)
12. Time taken in journey by vehicle Hours Minutes
13. Name of the place up to which journey was performed by vehicle (describe in brief)
14. Conspicuous features observed during the journey by vehicle (describe in brief)
15. Time at which started on foot
16. Direction and distance covered on foot up to the reference point (km)
17. Conspicuous features observed during the journey on foot (describe in brief)
18. Time (hrs.) at which arrived at the reference point
19. Description of the reference point (describe in details)
20. Compass bearing from reference point to the plot approached for commencing survey Distance of the plot from reference point (mtr.)
21. Time of arrival at the Plot
22. Time of departure from the Plot
23. Time (hrs.) at which returned to the camp
24. Compassing done by
25. Distance measured by
26. Plot laid out by
27. Tree Enumeration done by
28. Height measurements taken by
29. B.T. and other measurements taken by
30. Bamboo enumeration done by
31. Bamboo weight taken by
32. References in the field written by
33. Remarks

Date : Signature of the Crew Leader

Diagrams etc.

A B

Field Form No. 2

PLOT DESCRIPTION FORM

Job No	Survey code	Form Code	Zone	Phy. Zone	State	District	Forest Division	Mapsheet No.	Grid code	Lat.	Long.	Legal Status	Land Use
	1	01											

Terrain Data						Soil Data							Crop Data												Bamboo Data				Plantation potential	Distance from road (km)	Distance from river/stream (m)	Plot status	Degraded Forest	
General Topography	Slope	Position on slope	Altitude	Aspect	Rockiness	Humus	Soil colour	Soil consistency	soil texture	Coarse Fragments	Soil depth	Soil erosion	Origin of stand	Crop composition	Canopy layer or storey	Top height	Size class	Intensity of regeneration	Species under regeneration	Injuries to crop	Fire incidence	Grazing incidence	Presence of weeds	Presence of grass	Bamboo density	Bamboo quality	Bamboo flowering	Bamboo regeneration					Biotic influence	Natural calamity

Date…………………..

Signature of the Crew Leader……………………………………

Name of the Crew Leader……………………………..…………

Field Form No. 3

PLOT ENUMERATION FORM

Job No.	Form Code	Mapsheet No.	Grid code
	02		

Total No. of bamboo clumps	Total No. of trees

Species Name		Species Name		Species Name		Species Name		Species Name		Species Name		Species Name		Species Name	
Code	Dia	Code	Dia	Code	Dia	Code	Dia	Code	Dia	Code	Dia	Code	Dia	Code	Dia

Date…………………..
Leader………………………………

Signature of the Crew
Name of the Crew Leader...

Field Form No. 4

SAMPLE TREE FORM

Job No.	Form Code	Mapsheet No.	Grid code
	03		

Total No. of trees

Species name	Tree serial No.	Species code	Dominance	DBH OB (cm)	DBT (mm)	Bark Void % (estimated ocularly)	Tree height (m)	Crown width (m)		Species name	Tree serial No.	Species code	Dominance	DBH OB (cm)	DBT (mm)	Bark Void %	Tree height (m)	Crown width (m)	
								CW1	CW2									CW1	CW2

Date…………………..

Leader……………………………………

Signature of the Crew

Name of the Crew Leader……………………………..……

Field Form No. 5

BAMBOO CLUMP ANALYSIS FORM

Job No.	Form Code	Mapsheet No.	Grid code
	04		

Average culm height (in dcm)		Bamboo quality
Upto 1 cm top dia	Upto 2 cm top dia	
72-74	75-77	78

Species		Clump Sl.No.	Clump Dia-meter (cms)	Clump size class	Green sound culm								Green damaged culms								Dry sound				Dry damaged culms				Deca-yed culms	Total no. of culms
Name	Code				Crrent year's	One to two years old				Over two years old			Current year's	One to two years old				Over two years old												
						1<2 cms	2<5 cms	5<8 cms	8+ cms	2<5 cms	5<8 cms	8+ cms		1<2 cms	2<5 cms	5<8 cms	8+ cms	2<5 cms	5<8 cms	8+ cms	1<2 cms	2<5 cms	5<8 cms	8+ cms	1<2 cms	2<5 cms	5<8 cms	8+ cms		

Date………………….. Signature of the Crew
Leader…………………………………… Name of the Crew Leader………………………………..…

Field Form No. 6

BAMBOO ENUMERATION AND ANALYSIS FORM (NON CLUMP FORMING)

Job No.	Form Code	Mapsheet No.	Grid code
	05		

Species			Green sound culm								Green damaged culms							Dry sound culms				Dry damaged culms				Deca-yed culms	Average culm height in dcm.	Total no. of culms
Name	Code	Current year	One to two year old				Over two year old				Current year's	One to two year old			Over two year old													
			1<2 cms	2<5 cms	5<8 cms	8+ cms	1<2 cms	2<5 cms	5<8 cms	8+ cms		2<5 cms	5<8 cms	8+ cms	2<5 cms	5<8 cms	8+ cms	1<2 cms	2<5 cms	5<8 cms	8+ cms	1<2 cms	2<5 cms	5<8 cms	8+ cms			

Date…………………..
Leader……………………………………

Signature of the Crew
Name of the Crew Leader……………………………..….

Field Form No. 7

BAMBOO WEIGHT FORM (both for culm and non culm forming bamboos)

Job No.	Form Code	Mapsheet No.	Grid code
	06		

Species		Sample No.	2 to under 5 cms					5 to under 8 cm					8 cm and over					Green weight of sub-sample for co-relation with dry weight		
Name	Code		Diameter in cms	Total length in dcm	Utilisable length in dcm		Weight in grams	Diameter in cms	Total length in dcm	Utilisable length in dcm		Weight in grams	Diameter in cms	Total length in dcm	Utilisable length in dcm		Weight in grams	Sub-sample culm 2 & under 5 cm dia	Sub-sample culm 5 & under 8 cm dia	Sub-sample culm 8 cm and over
					Upto 1 cm top dia	Upto 2 cm top dia				Upto 1 cm top dia	Upto 2 cm top dia				Upto 1 cm top dia	Upto 2 cm top dia				

Date………………….. Signature of the Crew

Leader…………………………………… Name of the Crew Leader…………………………..………

Note : - If inventory of Bamboo has been carried out earlier in the same area wherein green weight and dry weight have been taken, then the same may not be carried out again.

Field Form No. 8 REGENERATION FORM

Job No.	Form Code	Mapsheet No.	Grid code	Plot location	Slope	Altitude	Aspect	Regeneration Plot size: 3m ´ 3m = (0.0009 ha)

Regeneration					
Species		Diameter at breast height (cm)	No. of plants		
			Category of regeneration		
Name	Code		1	2	3

Date……………………………… Signature of the Crew Leader……………………..

Name of the Crew Leader……………………

Field Form No. 9 **SOIL AND FOREST FLOOR CARBON FORM**

Job No.	Form Code	Mapsheet No.	Grid code	Proportion of		Forest floor sample No.	Soil sample No.
				Gravel %	Soil%		

Note : The % of Gravel and Soil are measured ocularly.

Weight of Forest Floor in gms.				Volume of soil	Weight of soil (gms)
NE	NW	SW	SE		

Note : In India, soil and forest floor carbon data is collected from the NW and SE plots.

Date………………………… Signature of Crew
Leader…...…………………. Name of Crew Leader…………………………….

SOIL AND FOREST FLOOR SAMPLE CARD

(To be read with Field Form 9)

1. Mapsheet No. ______________________________

2. Grid Code ______________________________

3. District Name ______________________________

4. Sample No. ______________________________

5. Date of Collection ______________________________

Signature____

Name & Signature of Crew Leader______________________________

Form-B1 Data for estimation of biomass of shrubs, herbs and dead wood

Job No.	Form Code	Zone	Phy. Zone	State	District	Forest Division	Mapsheet No.	Grid code	Lat.	Long.	Legal Status	Land Use	Crop composition	Presence of Dead wood

Northern Sub-plot												Remarks
				Shrubs			Climbers			Herbs		
Dead wood information			Weight of litter (branch) (kg	Species name	Weight (kg.)		Species name	Weight(kg.)		Weight (gm.)	Species name	
Species code	Dbh (cm)	Wg (kg.).			Wood	Non Wood		Wood	Non Wood			

Name of crew leader.................... **Designation........................** **Signature........................** **Date: ....**

Form-B2 Data for estimation of biomass of trees below 10 cm dia

Job No.	Form Code	FSI Zone	Phy. Zone	State	District	Species name	Species code

S.No.	Dia at 1.37 m	Weight of wood (kg)	Weight of twigs (gm.)	Weight of leaves(gm.)	Weight of flower (gm.)	Weight of fruits (gm.)	Collar diameter (cm)	Remark
	0-1							
	0-1							
	0-1							
	1-2							
	1-2							
	1-2							
	2-3							
	2-3							
	2-3							
	3-4							
	3-4							
	3-4							
	4-5							
	4-5							
	4-5							
	5-6							
	5-6							
	5-6							
	6-7							
	6-7							
	6-7							
	7-8							
	7-8							
	7-8							
	8-9							
	8-9							
	8-9							
	9-10							
	9-10							
	9-10							

Signature
Name of crew leader...........................
Date: Designation ....

Note :

1. *The data collected from this form is to be used for Modelling purpose.*
2. *Weight of flowers and fruits (col 6&7) are to be taken if they are found present at the time of data collection. Otherwise they can be left blank.*

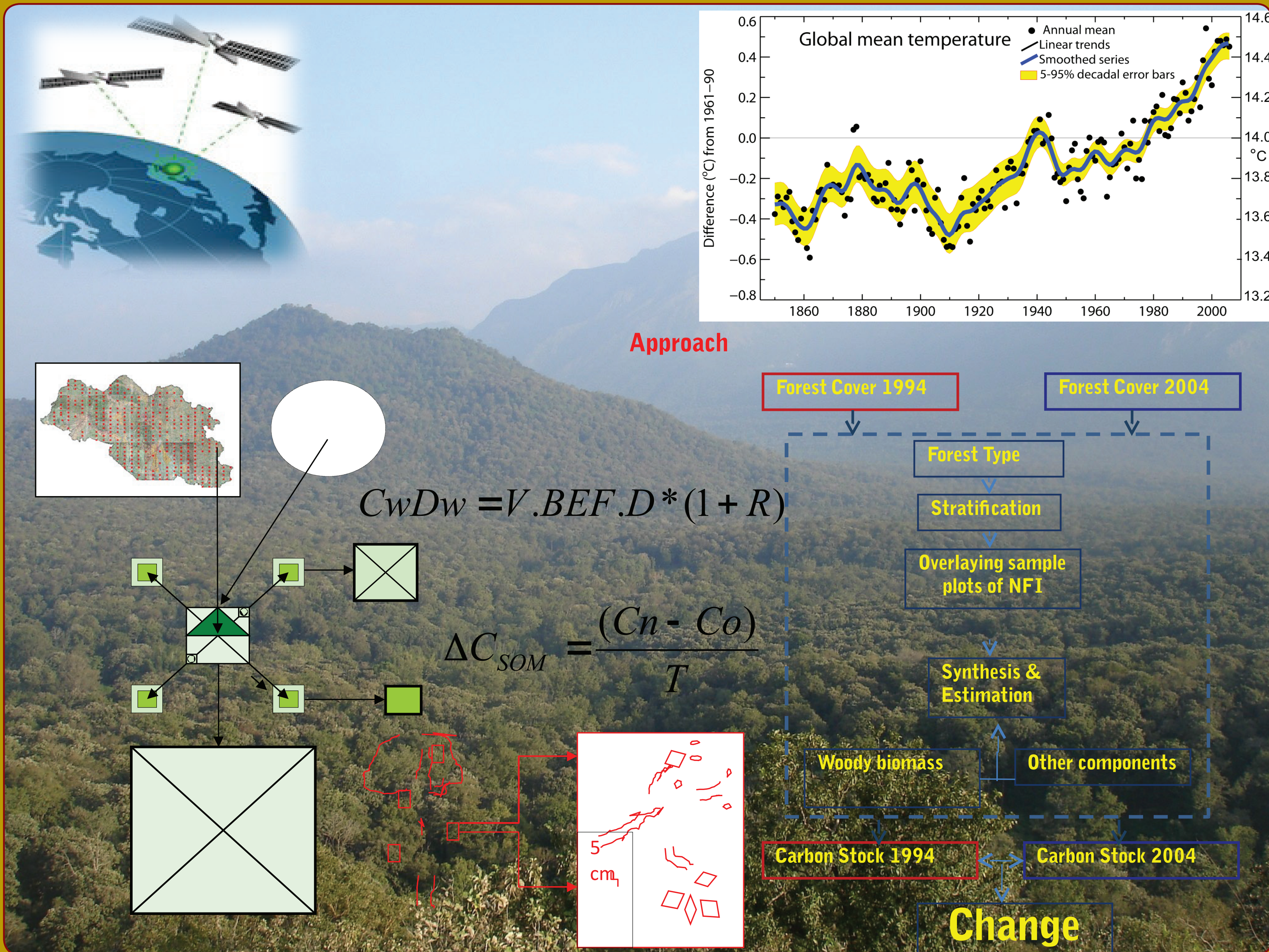
Form-B3

Data for estimation of biomass of branches, foliage etc of trees above 10 cm. dbh

Job No.	Form Code	FSI Zone	Phy. Zone	State	District	Species name	Species code

S.No	Dia class	Height (m.)	Crown height (m.)	CW1 (m.)	CW2 (m.)	Shape of crown	Blank in Canopy %	Weight of wood (kg.)	Weight of twigs (gm.)	Weight of leaves (gm.)	Weight of flowers (gm.)	Weight of fruits (gm.)	Remark (No. of leafs of palm like trees)
	10-20												
	10-20												
	10-20												
	20-30												
	20-30												
	20-30												
	30-40												
	30-40												
	30-40												
	40-50												
	40-50												
	40-50												
	50-60												
	50-60												
	50-60												
	60-70												
	60-70												
	60-70												
	70-80												
	70-80												
	70-80												
	80-90												
	80-90												
	80-90												
	90+												
	90+												
	90+												

Name of crew leader.................. Designation.............................. Signature.............................. Date: ....



MEASUREMENT AND ESTIMATION OF FOREST CARBON STOCK

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