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INTEGRATED PROTECTED AREA CO-MANAGEMENT (IPAC)

CERTIFICATE TRAINING COURSE ON CARBON FINANCING PROJECT PREPARATION

PHASE II: TRAINING ON CARBON PROJECT PLANNING AND CARBON POOL ASSESSMENT (31 OCT – 2 NOV 2009)

PHASE III: FIELD EXERCISE ON DEVELOPING SUNDARBANS MANGROVES CARBON PROJECTS: FIELD DEMONSTRATION (3 – 9 NOV 2009)

PHASE IV: TRAINING ON CARBON PROJECT IMPLEMENTATION (10 – 11 NOV 2009)

February 2010

This report is made possible by the support of the American People through the United States Agency for International Development (USAID). The contents of this report are the sole responsibility of International Resources Group (IRG) and do not necessarily reflect the views of USAID or the United States Government.

INTEGRATED PROTECTED AREA CO-MANAGEMENT (IPAC)

CERTIFICATE TRAINING COURSE ON CARBON FINANCING PROJECT PREPARATION

PHASE II, PHASE III, PHASE IV

Phase 2: 31 Oct – 2 Nov 2009, Phase 3: 3 – 9 Nov 2009, Phase 4: 10-11 Nov 2009

Venue: Fisheries Training Academy (Phase 2 & 4)
Organized By : Integrated Protected Area Co-Management Project (IPAC)

USAID Contract N° EPP-1-00-06-00007-00
Order No : EPP-I-01-06-00007-00

Submitted to :
USAID/Bangladesh

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Submitted for :
International Resources Group (IRG)
With subcontractors:
WWF-USA, dTS, East-West Center
Environmental Law Institute, Epler-Wood International
World Fish Center, CIPD, RDRS, CODEC
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PHASE II: TRAINING ON CARBON PROJECT PLANNING AND CARBON POOL ASSESSMENT

31 October - 02 November, 2009

The phase two of Certificate Training Course on Carbon Financing Project Preparation course from October 31 to November 02, 2009 was implemented at Fisheries Training Academy, Savar, Dhaka (Annex ...: Course schedule). Out of 25 participants (Annex ...: Participants List) 23 attended from GOB departments viz. 11 from Forest Department of which one Assistant Chief Conservator of Forests, four Divisional Forest Officers/Deputy Conservator of Forests, and six Assistant Conservator of Forests; seven from Department of Fisheries of which one District Fisheries Officer, one Assistant Director, five Senior/Upazila Fisheries officers; five from Department of Environment of which one Deputy Director, one Assistant Director, two analyst and one Research Officer. Rest two full time observers were attended viz. one Assistant Professor from Independent University of Bangladesh and one Ex-Deputy Director (Forest Inventory Division) from Bangladesh Fisheries Research Institute. The following report highlights with the sessions with resource person's names and along with session materials**:**

31 October 2009

1. Presentation on overview of the planning, design and development of land-use carbon projects by Dr. J. Boone Kauffman, US Forest Service.
2. Presentation on land-use carbon project design standards by Dr. Ram A. Sharma, Deputy Chief of Party, IPAC project.
3. Presentation on international and national carbon markets (regulatory and voluntary) by Mr. Todd Johnson, IRG, Washington, D.C.
4. Presentation on overview of mangrove carbon project (IPFCS) and Sundarbans (role and values of mangroves by Dr. J. Boone Kauffman, US Forest Service.
5. Presentation on land-use carbon financing: access mechanisms and possibilities for Bangladesh by Mr. Todd Johnson, IRG, Washington, D.C.

01 November 2009

6. Presentation on benefits distribution and cost-benefit analysis of a land-use carbon project by Dr. Ram A. Sharma, Deputy Chief of Party, IPAC project.
7. Presentation on land tenure and land-use carbon project management in Bangladesh by Dr. Ram A. Sharma, Deputy Chief of Party, IPAC project.
8. Presentation on applying international carbon accounting standards at the project level: example of Sundarbans (introduce application of tier III components) by Mr. Daniel Donato, US Forest Service.
9. Presentation on developing a Project Initial Note (PIN) and Project Design Document (PDD) by Dr. Ram A. Sharma, Deputy Chief of Party, IPAC project.

02 November 2009

10. Presentation on establishing a carbon baseline for Sundarbans: remote sensing and field data (assessment past deforestation and degradation of an area) by Mr. John Campbell, US Forest Service.
11. Presentation on carbon pool quantification for Sundarbans mangroves carbon project: field method (how to assess IPCC standards for forest carbon pools) by Mr. Daniel Donato, US Forest Service.
12. Presentation on quality assurance/quality checks procedures by Ms. Melanie Stidham, US Forest Service.

PHASE III: FIELD EXERCISE ON DEVELOPING SUNDARBANS MANGROVES CARBON PROJECTS: FIELD DEMONSTRATION

03 – 09 November, 2009

03 November 2009

All the training participants started journey to Khulna from Dhaka by bus accompanied by Mr. Daniel Donato, Ms. Melanie Stidham and Mr. John Campbell from US Forest Service as trainers as well as Dr. Ram A. Sharma, Deputy Chief of Party, Mr. Kazi M. A. Hashem, Institutional Capacity Building Specialist; and Mr. Abdul Jalil, Site Facilitator from IPAC as coordinating members. Mr. A. K. M. Shamsuddin, IPAC Consultant also accompanied the team. They arrived Khulna in the evening, boarded on boat and sailed for Sundarbans. The boat stayed beside Harbariya Eco-Tourism Center in the Sundarbans East Division under Chandpai Range.

Mr. Ishtiaq Uddin Ahmad, Deputy Chief Conservator Forests and Mr. Md. Akbar Hossain, Conservator of Forests partially attended and Mr. Mihir Kanti Doh, Divisional Forest Officer, were full time observers there.

Moreover, two Range Officers and four Beat Officers were also involved in the field practicum process as they will be involved in actual surveying process immediately after the training.

04 November 2009

The trainers' viz. Mr. Daniel Donato, Ms. Melanie Stidham and Mr. John Campbell demonstrated the use of measuring tape, diameter tape, compass, range finder, clinometers, GPS, etc. to the participants at Harbariya Eco-Tourism Center. Each of the participants was familiarized with all of the equipments along with practiced for actual survey.

The trainers also discussed and demonstrated the procedure of measuring a carbon inventory sample plot. The participants were informed about the size of sample plots, measuring and counting trees, saplings, seedlings, woody debris, etc. They also knew about destructive harvest and method of collection of non-timber products for bio-mass estimation. The trainers also showed the use of oven for bio-mass drying.

Then the participants were divided into three groups (Annex ...: Group Wise Participants List). Each group members also practiced soil boring tools **to** collect soil from one meter depth and preserving soil in the plastic containers.

The teams were also assigned for drafting PDD during the field trip (evening of each day) for plenary presentation on November 11 at Fisheries Training Academy.

05 November 2009

As per decision the teams started towards Plot # 451 by GPS navigation along with Mr. Ishtiaq Uddin Ahmad and Mr. Md. Akbar Hossain and arrived at the exact plot. The team measured and collected all the information/data for the inventory as guided by the US Forest Service trainers. All the participants practiced each method/equipments for measuring a sample plot. The trainers involved all participants in the evening for reviewing whole day's experience for reinforcing learning.

06 November 2009

The three teams started for Plot # 562 navigated by GPS. But they could not reach the plot center because of obstacle of a canal. They had to stop before 200 meters from the plot center. They measured and collected all data there as guided by the resource persons. The trainers involved all participants in the evening for reviewing whole day's experience for reinforcing learning.

07 November 2009

The teams intended to go to sample Plot # 506 but could not reach at the plot center. They had to finish their journey 400 meters away from the center due to canal. However, they practiced as it was done on previous day. The trainers involved all participants in the evening for reviewing whole day's experience for reinforcing learning.

08 November 2009

The team was engaged at Harbariya Eco-Tourism Center in collecting seedlings by destructive harvest. Participants also collected woody debris of different sizes.
The resource persons informed about the protocol of measuring sample plots and collecting seedlings, debris, etc. They also gave idea about the calculation of collected data. The trainers involved all participants in the evening for reviewing whole day's experience for reinforcing learning.

09 November 2009

Started journey by bus from Mongla and reached Savar Fisheries Training Academy in the evening. Thus the Phase III of Certificate Training Course on Carbon Financing Project Preparation course was over and done.

PHASE IV: TRAINING ON CARBON PROJECT IMPLEMENTATION

10 – 11 November, 2009

10 November 2009

1. The class room session on discussions and questions from field activities were facilitated by Mr. Daniel Donato and Ms. Melanie Stidham. Basically the discussion was concentrated on the technical aspects e.g. how to measure top dying trees, half live and half dead, what to do if there is canal in the center of a plot, etc.
2. The next session was also facilitated by Mr. Daniel Donato and Ms. Melanie Stidham on carbon project data management. They emphasized on data quality of collection, presentation and accuracy of data keeping.
3. Presentation on biomass and carbon density computations by Mr. Daniel Donato.
4. The session on quantifying and reporting uncertainty was also presented by Mr. Daniel Donato.
5. Discussed guidelines in the session on Sundarbans mangroves carbon project: reporting.
6. Finally the two groups were assigned for preparing, reviewing and finalizing PDD on Sundarbans for plenary presentations.

11 November 2009

The teams were engaged separately at Fisheries Training Academy for reviewing and finalizing PDD on Sundarbans for plenary presentations until 02:30 pm.

A plenary session was organized in the afternoon where the teams presented their summary presentations. The participants interacted after each group presentation and thus enriched their knowledge on PDD process.

At the end, one representative from each of the participating departments, resource persons and IPAC reflected their major learning and shared feelings on the entire course.

Closing ceremony: Immediately after the plenary session a closing ceremony was organized where the Chief Guest was Mr. Md. Abdul Motaleb, Chief Conservator of Forests, Forest Department and the Special Guests were Mr. Daniel Donato, Research Ecologist, US Forest Service and Mr. Md. Shahid Ullah Bhuiyan, Director, Fisheries Training Academy. The closing ceremony was chaired by Mr. Ishtiaq Uddin Ahmad- Deputy Chief Conservator of Forests, Forest Department.

All the guests spoke on this occasion also Mr. Md. Abdul Motaleb, Chief Conservator of Forests along with other guests awarded certificate to the course participants.

Mr. Robert T. Winterbottom, Chief of Party, IPAC Project expressed vote of thanks to all concerned finally.

ANNEX I: COURSE SCHEDULE

Certificate Training Course on Carbon Financing Project Preparation

Updated Summary Description and Schedule

Course Objectives

The overall objective of Certificate Training Course on Carbon Financing Project Preparation is to contribute to the adaptation and mitigation of climate change and to promote sustainable development of natural resources by focusing the capacity of IPAC's partner ministries such as Ministry of Environment and Forests, and Ministry of Fisheries and Livestock, and partner government agencies including Forest Department (FD), Department of Fisheries (DOF) and Department of Environment (DOE) to access national and international carbon markets.

The course will aim to provide participants with the knowledge, mechanisms and practical tools to effectively package land-use carbon projects for the regulatory and/or voluntary markets.

Main purpose of the course will focus on an overview of climate change policy framework and land-use carbon projects mainly for senior and mid-level officials as well as practical guidance on thinking through practical issues, principles and methods, and navigating the logistics of project planning, design, development and effective field implementation.

Course Participants

Seventy five participants are targeted for Phase I which will be conducted at Radisson Water Garden Hotel, Dhaka. Twenty five participants will continue to attend the remainder Phase II, III and IV. The selection of these participants may be as below:

Fifty participants for Phase I will be senior government officials and representatives of relevant organizations which are involved in climate change related issues at policy level. This may include senior officials from the Ministry of Environment & Forests, Ministry of Fisheries & Livestock, Ministry of Land, Ministry of Water Resources, Ministry of Finance, IMED and Planning Commission, and representatives from BCAS, IUCN, BELA, Arannayk and other organizations including universities. The Government Agencies that may be covered for the senior level participation will include Department of Fisheries, Department of Environment, Forest Department, Department of Agriculture Extension, etc.

The remainder 25 participants, after attending Phase I program, will continue to attend Phase II, III and IV and will be identified amongst mid-level officials mainly from DOF (Eight DFOs, Assistant Directors/SUFO), DOE (Six Deputy Directors and Assistant Directors) and FD (11 DFOs and ACFs). It is worth mentioning here that DOE has a climate change cell which will be involved in this training.

Course Description

The Certificate Training Course on Carbon Financing Project Preparation will take place in the following 4 Phases:

Phase I :	Workshop on Global Climate Change and Carbon Financing: Opportunities for Bangladesh Venue : Radisson Water Garden Hotel, Dhaka
Phase II :	Training on Carbon Project Planning, Design and Carbon Pool Assessment Venue : Fisheries Academy, Savar, Dhaka
Phase III :	Field Exercise on Developing Sundarbans Mangroves Carbon Projects : Field Demonstration Venue : Sundarbans Reserved Forests
Phase IV :	Training on Carbon Project Implementation Venue : Fisheries Academy, Savar, Dhaka

Phase I (28-29 October), targeting senior and mid-level government officials from the relevant ministries and government agencies, will focus on an overview of emerging global climate change issues, local options and implications for land-use sectors in Bangladesh.

Bangladesh Action Plan for Climate Change will be discussed in order to focus on climate change mitigation and adaptation projects that can be taken up for land-use sectors by mobilizing domestic resources and international funds.

A snapshot of the project design and development processes will be presented by focusing on Land-Use, Land-Use Change and Forestry (LULUCF) and Reduced Emissions from deforestation and degradation (REDD) by describing field examples from Bangladesh.

Phase II (31 Oct.-2 Nov.), targeting mid-level officials from IPAC partner government agencies (FD, DOF and DOE), will address land-use carbon project planning, design and development. It will include a review of the main components of land-use carbon projects, the key issues regarding feasibility and standards, the Project Design Document (PDD), methodologies and tools for making initial and ongoing measurements of carbon pool, and non-carbon risks and benefits.

Chunoti Carbon Forestry Project will be taken as a case study for describing required efforts and steps needed for developing a land-use project that can be funded by attracting regulatory and/or voluntary markets. Main focus will be on understanding, i) project's relevance and contribution towards Bangladesh's national plans and development goals including poverty alleviation and biodiversity conservation, ii) approved baseline and monitoring methodologies, iii) estimation of ex ante net anthropogenic GHG removals by land-use sinks, and estimated amount of net anthropogenic GHG removals by land-use sinks over the chosen carbon credit period, iv) potential barriers related to key issues, v) monitoring and reporting plan, and cost, and vi) assessment of environmental and socio-economic impacts.

Main principles, tools and procedures related to a REDD Project Development for Sundarbans Reserved Forests (SRF) will be covered in this Phase in order to prepare the participants for field demonstrations that will be carried out in Phase III as described below.

Phase III (3-9 Nov.) will be implemented in SRF to conduct and collect the assessments and necessary data to package a REDD project for Sundarbans mangroves for either voluntary or regulatory markets.

Phase IV (10-11 Nov.) will focus on deliberating land-use carbon project implementation issues, implications and options available for a least developed country such as Bangladesh that is vulnerable to adverse impacts of climate change. Sessions on host country approvals (by Designated National Authority), sales and marketing of land-use carbon projects in international and national markets including conservation financing, validation/certification, verification, relevant forms and documents, funding options both from national (climate change fund) and international multi-lateral and bilateral organizations), and future pathways.

Schedule - Certificate Training Course on Carbon Financing Project Preparation

Date	Timing	Session	
28 October	4:45 pm	Registration	JU/IUB and IPAC team
	5:00 pm	Address of Welcome	Mr. Joynal Abedin Talukder, Project Coordinator, IPAC Project, MoEF
	5:05 pm	Introductory Presentation: Climate Change, Forests and Carbon - Process and Market Mechanisms	Dr. Boone Kaufmann, US Forest Service
	5:15 pm	Keynote Address: Global Climate Change and Bangladesh: Potential of Bangladesh to earn Carbon Credits	Dr. Mihir Kanti Majumder, Secretary, MOEF
	5:25 pm	Address by the Special Guest	Mr. James F. Moriarty, US Ambassador to Bangladesh
	5:35 pm	Address by the Special Guest	Dr. Hasan Mahmud, State Minister, Environment and Forests
	5:45 pm	Address by the Chief Guest	Mr. Md. Abdul Latif Biswas, Minister, Fisheries and Livestock
	5:55 pm	Vote of Thanks	Mr. Robert T. Winterbottom, Chief of Party, IPAC Project
	6:00 pm	Snacks/Tea	
29 Oct.	9:00 am	Integrating forestry in global climate change mitigation and adaptation: Introduction	Dr. Boone Kaufmann, U. S. Forest Service
	9:20 pm	Overview of the natural resources of Bangladesh and opportunities for combating climate change, reducing poverty and conserving biodiversity	Mr. Md. Abdul Motaleb, Chief Conservator of Forests, Forest Department, Ministry of Environment and Forests
	9:40 am	Global Climate Change and its impact on agriculture, fisheries, forests and food security in Bangladesh	Dr. Z Karim, former Secretary and Senior Policy and Institutions Advisor, IPAC
	10:00 am	The international business of climate change: global context of carbon markets and trading	Todd Johnson, International Resources Group, Washington, D.C.
	10:20 am	Opportunities for carbon trading in	Mr. Abu Mostafa Kamal Uddin,

		Bangladesh	Program Manager, Climate Change Cell, DOE
	10:40 am	Perspective on Carbon Financing and Combating Climate Change in Bangladesh	Mr. Asaduzzaman, BIDS
	11:00 am	Tea	
	11:20	IPAC and USFS Collaboration in Climate Change Mitigation and Adaptation	Bob Winterbottom, IPAC COP
	11:40 am	Carbon Financing: Bangladesh Experience	Mr. AHM Maqsood Sinha, Managing Partner, Waste Concern
	12:00 pm	International Cooperation on Climate Change : Pathways to a Global Agreement	Todd Johnson, IRG/Washington
	12:20 pm	Ecosystem based options for adaptation and REDD: Opportunities for Bangladesh	Dr. A. Nishat, IUCN
	12:40 pm	General Discussion	
	1:00 pm	Lunch	
	2:00 pm	Climate change mitigation and adaptation strategies in the natural resources sector: A case for REDD for Sundarbans	Dr. Boone Kaufman, Daniel Donato and Melanie Stidham, US Forest Service
	2:20 pm	Land-Use Carbon Project Design and Development: A case study of Chunoti Wildlife Sanctuary	Dr. Ram Sharma, IPAC DCOP
	2:40 pm	Way forward: capitalizing on opportunities for Bangladesh	Dr. Boone Kaufman, Todd Johnson
	3:00 pm	Summary Overview of Discussions	Mr. Ishtiaq Uddin Ahmad, CF, Wildlife & Nature Conservation Circle & DCCF (Education), FD
	3:15 pm	Concluding Remarks	Ms. Denise Rollins, USAID Mission Director
	3:30 pm	Closing Statement	Dr. Mihir Kanti Majumder, Secretary, MoEF
	3:45 pm	Closing Statement	State Minister, MoEF
30 Oct – Friday – rest day – informal coordination meeting: USFS, USAID, IPAC			
Phase II: Training on Carbon Project Planning, Design and Carbon Pool Assessment			
31 Oct.	9:30 am	Introduction : Overview of Climate Change and IPAC	Azharul Mazumder, USAID
	10:15 am	Overview of the planning, design and development of Land-use Carbon Projects	Boone, Daniel, and Melanie
	11:30 am	Tea Break	
	11:30 am	Land-Use Carbon Project Design Standards	Ram
	12:30 am	International and National Carbon Markets (Regulatory and Voluntary)	Todd Johnson
	2:00 am		

	2:30 am	Overview of Mangrove Carbon Project (IPFCS) and Sundarbans (role and values of mangroves)	Boone, Daniel, and Melanie
	3:30 am	Land-use Carbon Financing : Access Mechanisms and Possibilities for Bangladesh	Todd Johnson
	4:50 pm	Recapitulation	Hashem
1 Nov.	9:00 am	Benefits Distribution and Cost-Benefit Analyses of a Land-use Carbon Project	Ram
	10:00 pm	Environmental and Socio-economic impacts of a Land-use Carbon Project in Bangladesh	Azhar
	11:15 am	Tea Break	
	11:30 am	Land Tenure and Land-use Carbon Project Management in Bangladesh	Ram
	12:15 pm	Applying international carbon accounting standards at the project level : Example of Sundarban (introduce application of tier III components)	Daniel, Melanie
	1:00 pm	Potential barriers related to land-use projects in Bangladesh : additionally, leakage, permanence and governance	Ram
	2:00 pm	Lunch	
	3:00 pm	Design of a Sundarbans Carbon Project	Daniel, Melanie
	4:00 pm	Developing a Project Initial Note (PIN) and Project Design Document (PDD)	Ram
	4:50 pm	Recapitulation	Hashem
2 Nov.	9:00 am	Establishing a Carbon Baseline for Sundarbans : Remote sensing and field data (assessing past deforestation and degradation of an area)	John C., Daniel
	10:00 am	Carbon Pool Quantification for Sundarbans Mangroves Carbon Project : Field Methods (how to assess IPCC standards for forest carbon pools)	Daniel, Melanie
	11:15 am	Tea Break	
	11:30 am	Carbon Pool Quantification for Sundarbans Mangroves Carbon Project : Field Methods (cont.)	Daniel, Melanie
	2:00 pm	Lunch	
	3:00 pm	Quality Assurance/Quality Check Procedures	Melanie Daniel
	4:00 pm	Discussions & Questions	Hashem and others
	4:45 pm	Recapitulation	Hashem
Phase III: Field Exercise on Developing Sundarbans Mangroves Carbon Projects: Demonstration of assessment techniques and required fieldwork			
3 Nov	Dhaka to Sundarbans		
4-8 Nov	Sundarbans Mangroves Carbon Project Planning, Design and Demonstration • Required preparations • Carbon pool identification • Stratification and sampling design • Formats and field data collection for assessing carbon pool		

	• Carbon analyses • Development of PDD	
9 Nov	Sundarbans to Dhaka	
Phase IV: Training on Carbon Project Preparation and Implementation		
10 Nov.	9:00 am	Discussions & Questions from field activities (Daniel, Melanie)
	10:00 am	Carbon Project Data Management
	11:00 am	Tea Break
	11:15 am	Biomass and carbon density computations
	1:15 pm	Quantifying and reporting uncertainty
	2:00 pm	Lunch
	3:00 pm	Sundarbans Mangroves Carbon Project : Reporting
	4:00 pm	Participants finalize a PDD for Sundarbans in groups of five
	4:45 pm	Recapitulation
11 Nov.	9:00 am	Participants outline a PDD for Sundarbans in groups of five (cont'd)
	11:00 am	Tea Break
	11:15 am	Writing continues
	1:30 pm	Lunch
	2:30 pm	Plenary Sessions
	4:45 pm	Ways forward
	5:00 pm	Closing
12 Nov	11:00 am	Presentation of Certificates to Training Workshop participants

ANNEX II: PARTICIPANT LIST

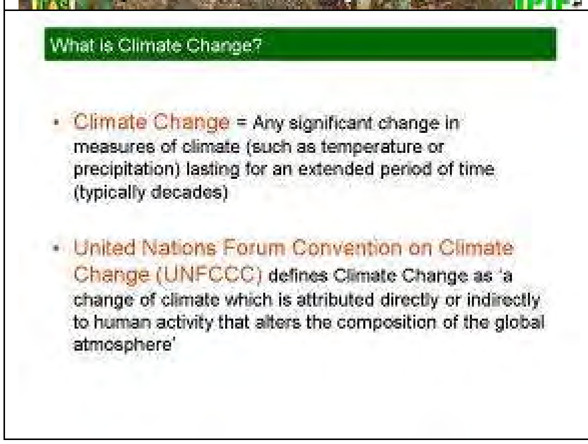
Certificate Training Course on Carbon Financing Project Preparation
Fisheries Training Academy, Savar

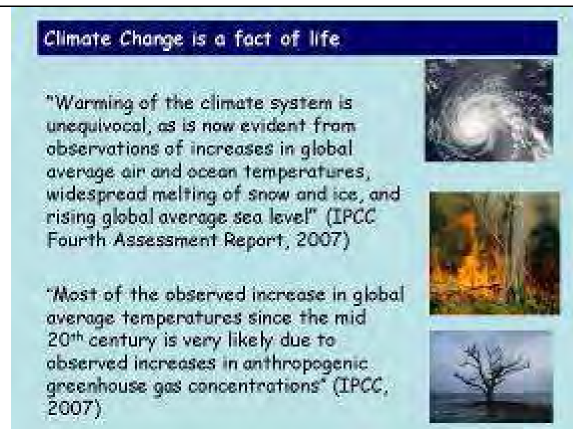
October 28 – November 11, 2009

Sl.	Name	Designation	Department
01	Md. Mozaharul Islam	Assistant Chief Conservator of Forests	FD
02	Md. Rakibul Hasan Mukul	Divisional Forest Officer	FD
03	Md. Abdul Awal Sarker	Divisional Forest Officer	FD
04	Abu Naser Md. Yasin Newaz	Divisional Forest Officer	FD
05	Md. Zaheer Iqbal	Deputy Conservator of Forests	FD
06	Imran Ahmed	Assistant Conservator of Forests	FD
07	Md. Subedar Islam	Assistant Conservator of Forests	FD
08	Md. Towfiqul Islam	Assistant Conservator of Forests	FD
09	Md. Abdur Rahman	Assistant Conservator of Forests	FD
10	Md. Oli Ul Haque	Assistant Conservator of Forests	FD
11	Mostafizar Rahman	Assistant Conservator of Forests	FD
12	Profulla Kumar Sarker	District Fisheries Officer	DOF
13	Tapan Kumar Paul	Assistant Director	DOF
14	Abdur Rouf	Senior Upazila Fisheries officer	DOF
15	Md. Zahid Hossain	Senior Upazila Fisheries officer	DOF
16	Md. Wahiduzzaman	Senior Upazila Fisheries officer	DOF
17	Monish Kumar Mondol	Senior Upazila Fisheries officer	DOF
18	ANM Azizul Islam Khan	Upazila Fisheries officer	DOF
19	Farid Ahmed	Deputy Director	DOE
20	Md. Abul Kalam Azad	Analyst	DOE
21	Md. Sadiqul Islam	Analyst	DOE
22	Md. Hassan Habibur Rahman	Research Officer	DOE
23	Md. Saidur Rahman	Assistant Director	DOE
24	Dil Rowshan	Assistant Professor	IUB
25	Sukumar Das	Ex-Deputy Director	BFRI

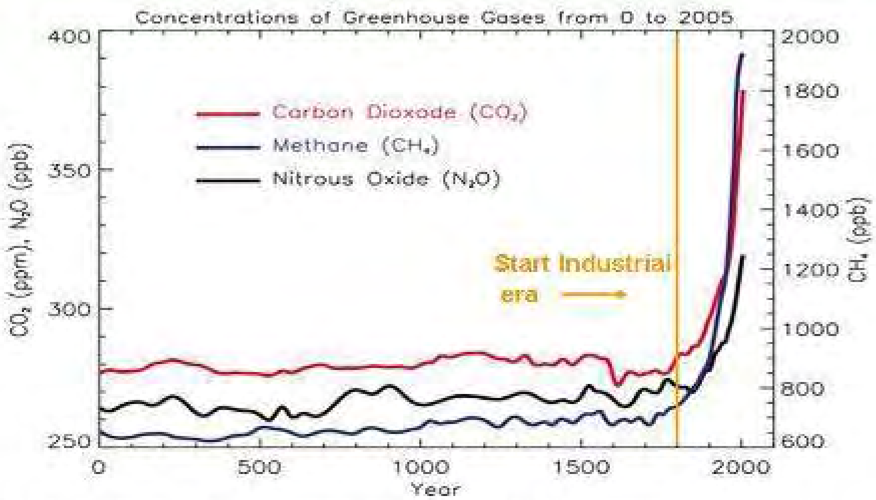
ANNEX III: PRESENTATIONS

PRESENTATION 1: OVERVIEW OF THE PLANNING, DESIGN, AND DEVELOPMENT OF LAND-USE CARBON PROJECTS. J. BOONE KAUFFMAN, DANIEL DONATO, MELANIE STIDHAM, USFS

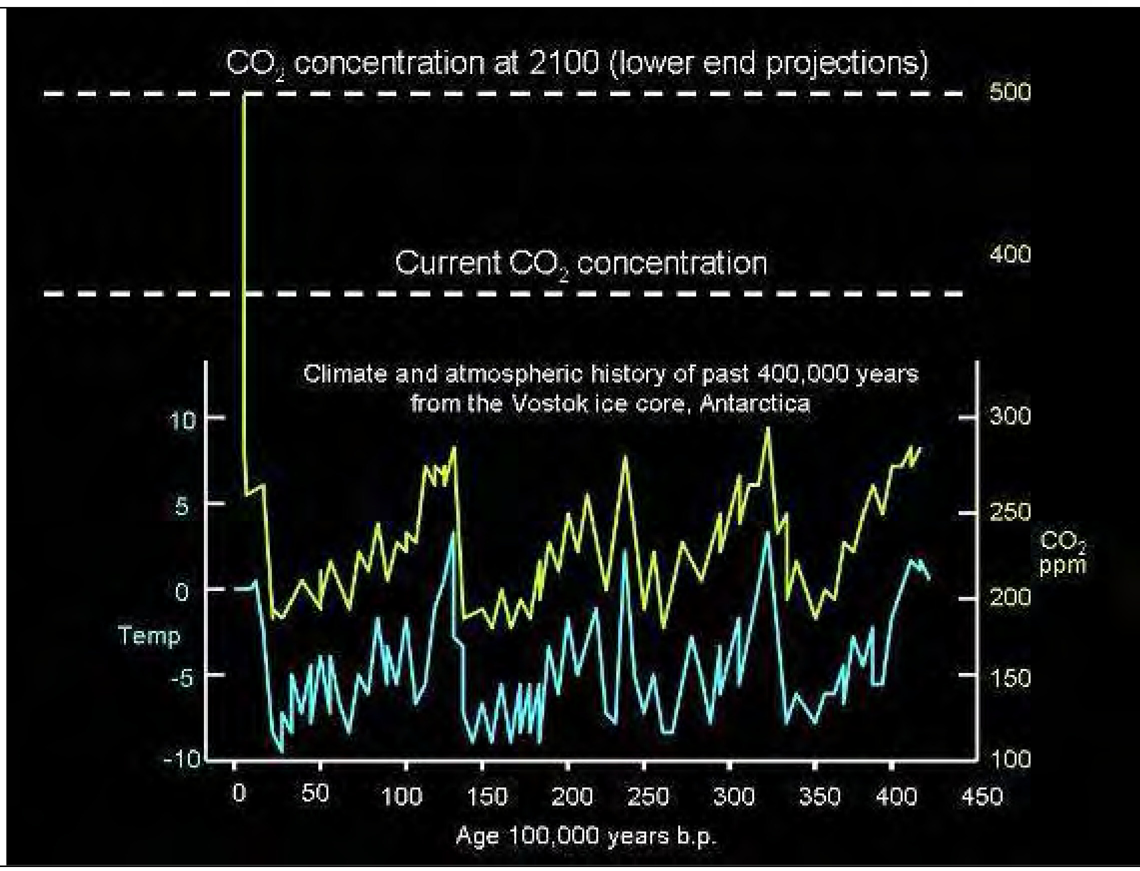




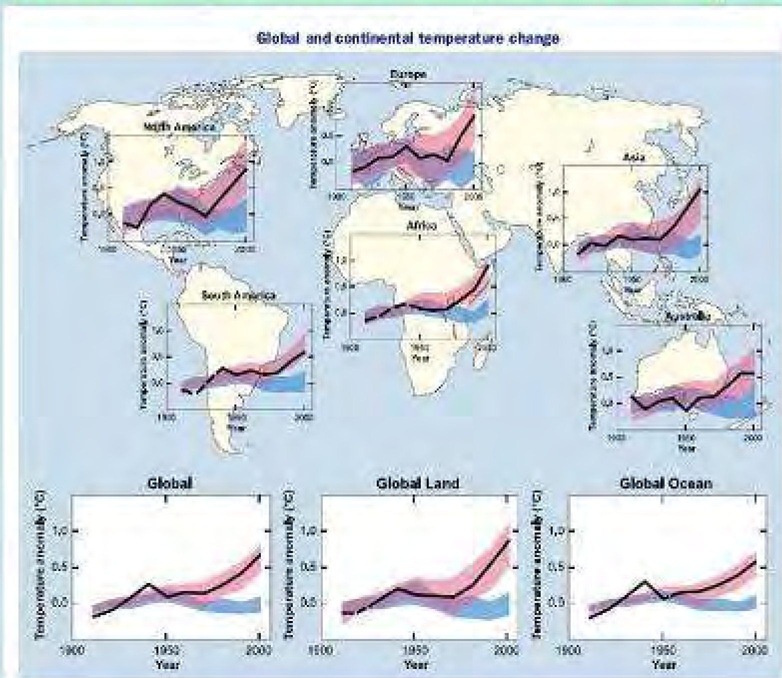
How rapidly are GHG concentrations rising?



- CO_2 levels are the highest in last 650,000 years
- In the last 50 yrs, CO_2 levels have grown more rapidly than ever before
- CO_2 levels are increasing 1.5- 2 ppm/yr



Global and continental temperature change



— **Observed temperatures**

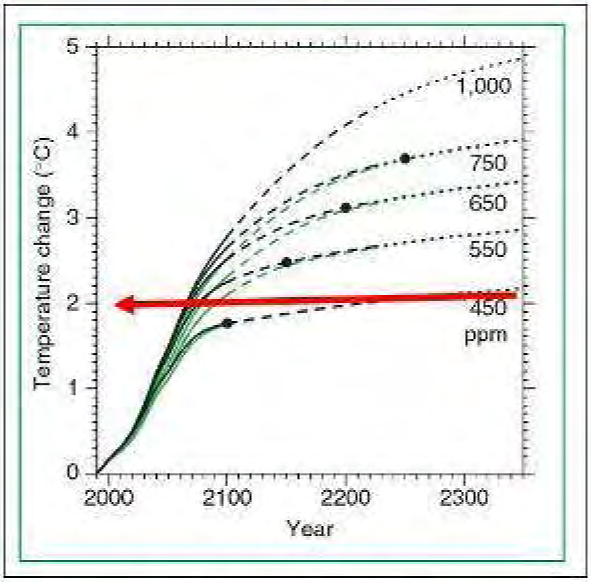
Model predictions (including natural and human drivers)

Model predictions (including only natural drivers)

Global Changes- How will it affect tropical countries?

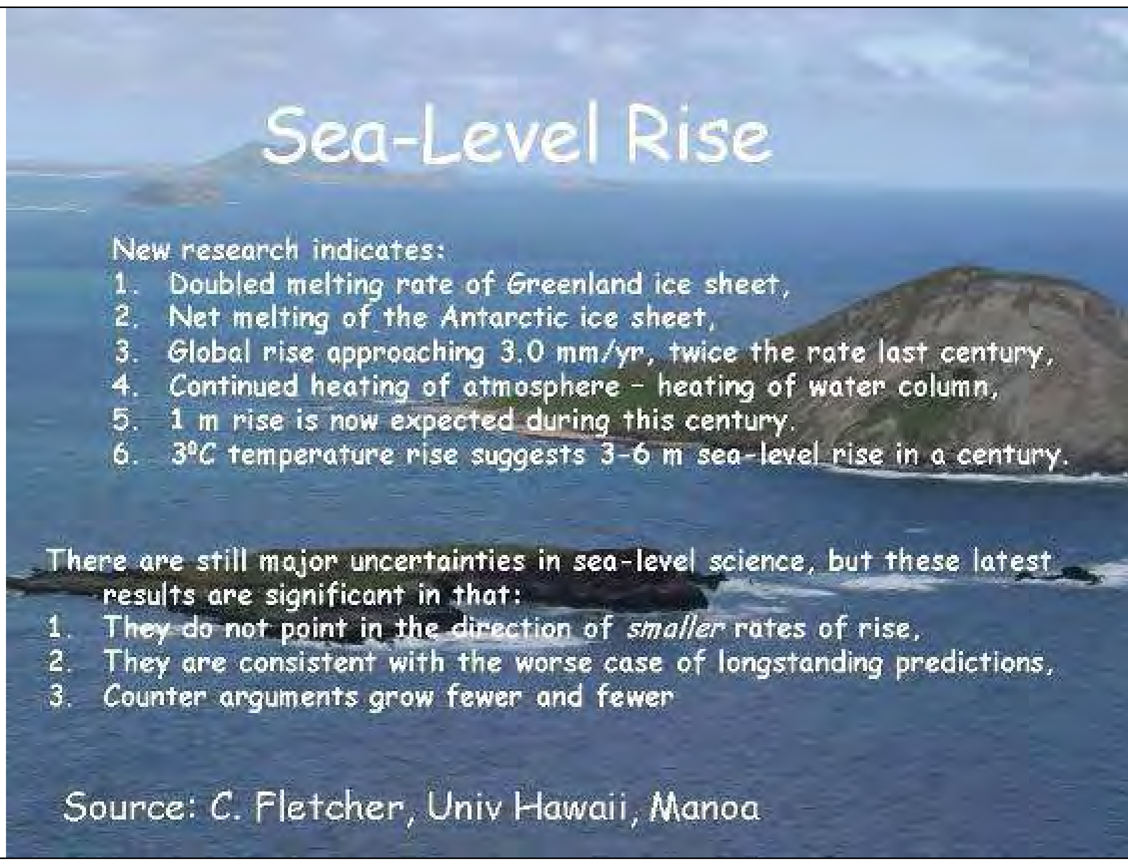
- Changes in temperature
- Increased El Niño events-droughts
- Increased severity of typhoons
- Increases in sea level
- Coral Bleaching
- Ocean Acidification

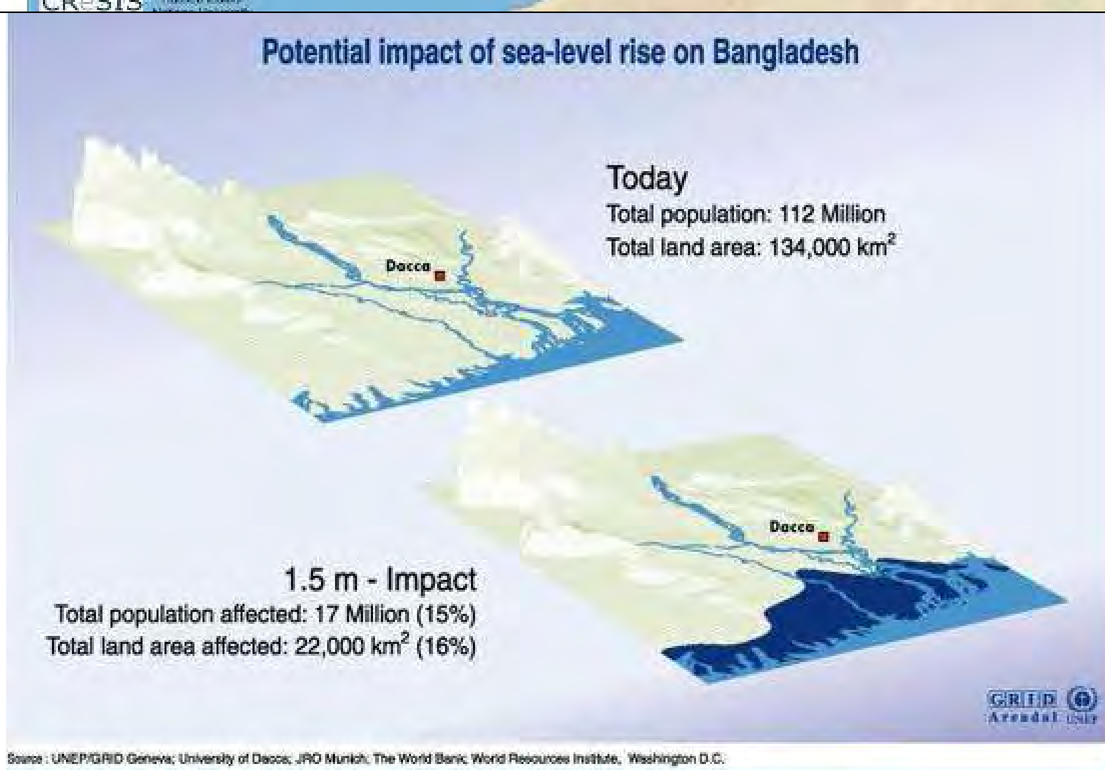
How much will temperatures rise?



Adapted from: IPCC Fourth Assessment Report (2007), Working Group 3

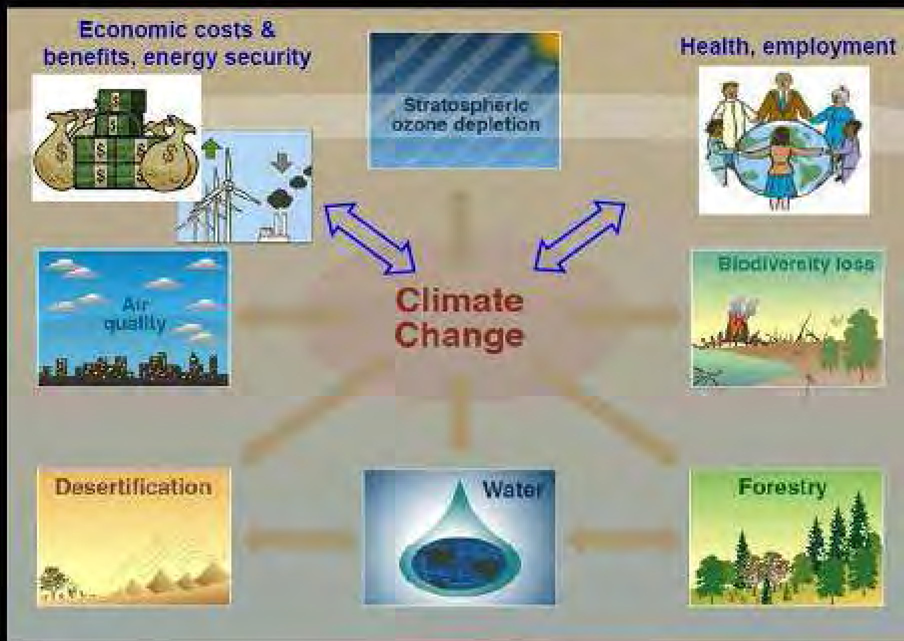
- Global temperatures will be determined by atmospheric GHG concentrations
- Many groups are advocating a target of 450 ppm to prevent temperature changes of more than 2 °C





As sea level rises, 35 million from Bangladesh will become environmental refugees by 2050 (IPCC).

Climate change is likely to change all aspects of human life



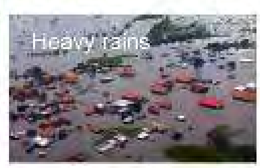
Impacts of climate change

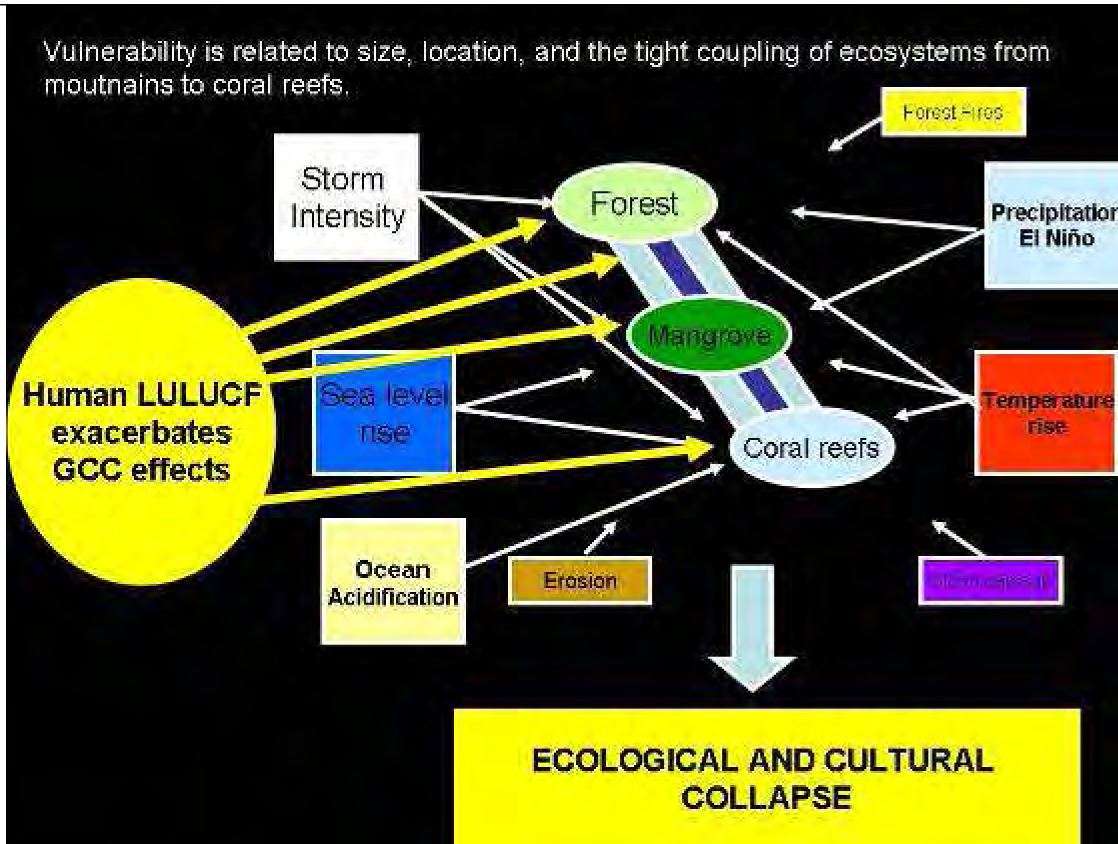
Impacts on human communities and livelihoods

Impacts on water supplies

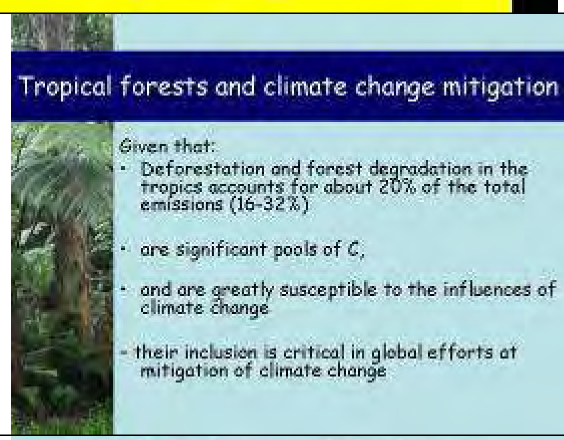
Impacts on agriculture

More extreme weather events




Vulnerability is related to size, location, and the tight coupling of ecosystems from moutnains to coral reefs.
Forest Fires
Storm Intensity
Forest
Precipitation El Niño
Mangrove
Human LULUCF exacerbates GCC effects
Sea level rise
Temperature rise
Coral reefs
Ocean Acidification
Erosion
ECOLOGICAL AND CULTURAL COLLAPSE

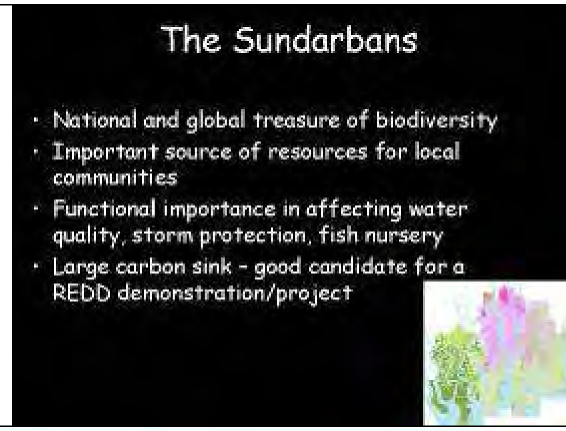

Ecosystems are strongly linked at watershed and landscape scales where degradation of one ecosystems affects all others
The Betsiboka R., Africa

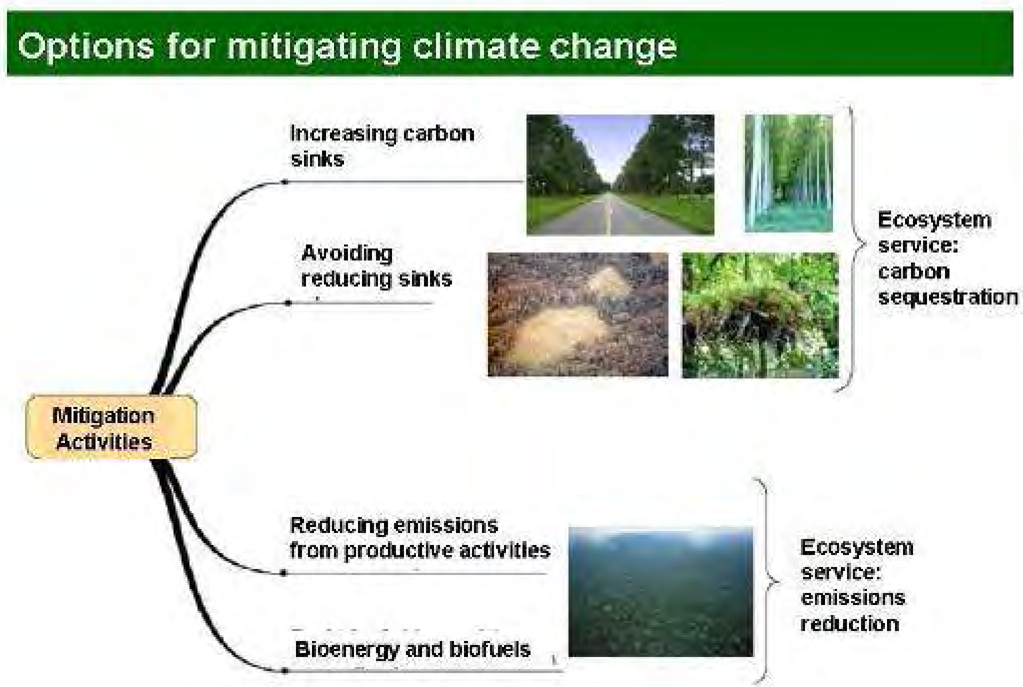

Tropical forests and climate change mitigation
Given that:
• Deforestation and forest degradation in the tropics accounts for about 20% of the total emissions (16-32%)
• are significant pools of C,
• and are greatly susceptible to the influences of climate change
- their inclusion is critical in global efforts at mitigation of climate change

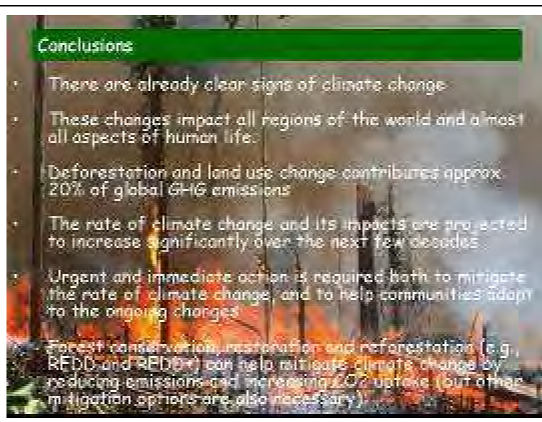

REDD - Reducing Emissions from Deforestation and Forest Degradation
REDD mechanisms use market/financial incentives to reduce the emission of greenhouse gases from deforestation and forest degradation.


The 13th Conference of the Parties (COP-13) in Bali, Indonesia (December 2007)
• Called for the inclusion of REDD as part of a post-2012 mitigation strategy.
• The 'Bali Road Map' conclusively stated that the technical capacity to accurately measure and monitor emissions reductions from reduced deforestation and degradation exists.
• Recognizes that the needs of local and indigenous communities have to be considered.
• Calls for demonstration activities and capacity building for countries that may not be ready to engage in the mechanism by 2012.

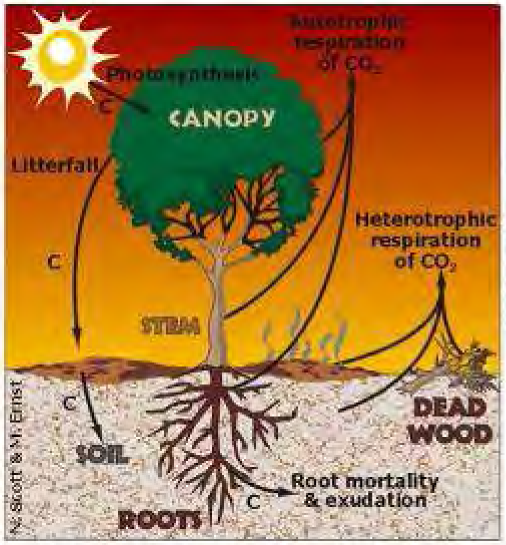

Objectives of the workshop
• Review and discuss climate change adaptation and mitigation approaches appropriate for Bangladesh forests
• Describe and define components of REDD projects and describe how this could work for the Sundarbans
• Provide instruction on how to effectively measure C pools, calculate baselines, and establish reliable, transparent and accurate monitoring protocols – information critical for REDD projects.
• Contribute to increasing the infrastructure capacity needed to accomplish the sustainability of biodiversity and provision of ecosystem services from the largest mangrove forest on earth


The Sundarbans
• National and global treasure of biodiversity
• Important source of resources for local communities
• Functional importance in affecting water quality, storm protection, fish nursery
• Large carbon sink – good candidate for a REDD demonstration/project


Options for mitigating climate change
Mitigation Activities
Increasing carbon sinks
Avoiding reducing sinks
Ecosystem service: carbon sequestration
Reducing emissions from productive activities
Bioenergy and biofuels
Ecosystem service: emissions reduction


Conclusions
• There are already clear signs of climate change
• These changes impact all regions of the world and almost all aspects of human life.
• Deforestation and land use change contributes approx 20% of global GHG emissions
• The rate of climate change and its impacts are projected to increase significantly over the next few decades
• Urgent and immediate action is required both to mitigate the rate of climate change, and to help communities adapt to the ongoing changes
• Forest conservation, restoration and reforestation (e.g., REDD and REDD+) can help mitigate climate change by reducing emissions and increasing CO2 uptake (but other mitigation options are also necessary).


Tropical forests
• Cover about 10% of the earth's land surface
• Store about 40% of the C residing in terrestrial vegetation
• Are large global C sinks and sources - (deforestation 1-3 Pg C atm flux; remaining forests a terrestrial sink of ~ 1 (-2) Pg C, Lewis 2006)
• Harbor between one-half to two-thirds of the world's species
• Provide many vital ecosystem services to humanity
• Small changes in tropical forest biome can potentially lead to major impacts to both biodiversity and global change



Carbon sequestration is an ecosystem service that has not received value until recently

Deforestation

- Releases CO_2 and other greenhouse gasses
- Decreases in the amount of C stored as biomass/organic matter
- Changes the albedo of the Earth
- Fragmentation of adjacent forest - increased decomposition, increased blow-down, and increased fire susceptibility

The synergism between land use and climate change

- The negative synergism between unsustainable land use and global climate change suggests great urgency in immediately addressing this global issue
- New financial incentives are needed to act as a countervailing force to the economic pressures of deforestation.

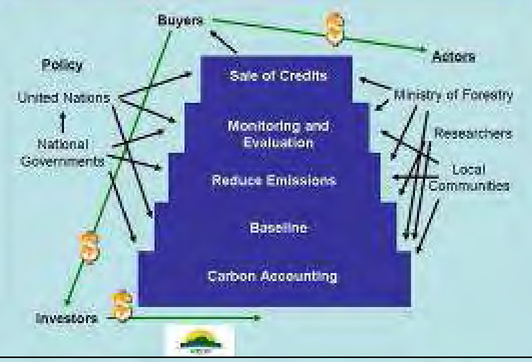
WHAT IS REDD?
Reduced emissions from deforestation or degradation

- Deforestation: The long term or permanent conversion of land from forested to non-forested. The direct human-induced conversion of forested land to non-forested land UNFCCC COP).
- Degradation - Changes within the forest which negatively affect the structure or function of stand or site and thereby lower the capacity to supply products or services (FAO).

REDD - Reducing Emissions from Deforestation and Forest Degradation

REDD mechanisms use market/financial incentives to reduce the emission of greenhouse gases from deforestation and forest degradation.

The Building Blocks of REDD



Technical aspects of REDD

- **Emissions Reductions Strategies**
  - establishment of protected areas
  - improved forest management
  - stopping or reducing forest fires,
  - practicing reduced impact logging,
  - ensuring that land conversion occurs in degraded areas rather than in intact forest land.
- Must credibly and verifiably reduce emissions
- Must be additional to actions that would have occurred in the absence of REDD financing
- Provide for permanent forest Protection

Technical aspects of REDD

- A fundamental challenge for REDD mechanisms to demonstrate **additionality**-
- Carbon emissions reductions that are additional to what would have occurred without the REDD mechanism.
- This requires knowledge of the baselines - the level of C emissions that would have occurred in the absence of the financial mechanism ("business as usual")

Additional to what?

Additional to the baseline.

Baseline: what is it?

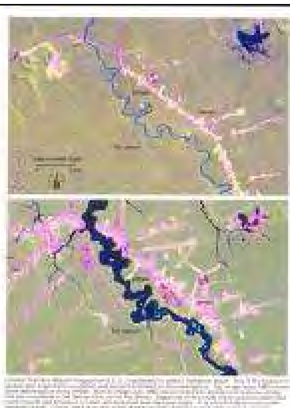
- Conditions at the start, before the project
- Reference emissions levels
- "Business as usual"
- "Without project"

- Basis to measure project impact
- Carbon credits will be counted as the difference between baseline emissions and emissions reduced by project activities

Baseline should describe the prevailing trends of deforestation or degradation.

Baseline: how determined?

- Historic
  - Based on sequence of past images;
  - Based on forest stats (total loss);
  - Based on other stats (population, etc.)
- Modeled
  - Regression analysis from predictive variables
- Negotiated
  - Countries set agreed to levels
- Current carbon stock



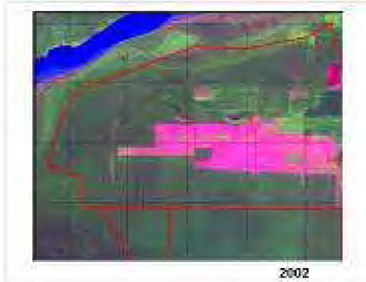
Baselines can be calculated with the combined use of remote sensing and ground studies.

Baselines

- Establishing C pools and predicting losses and gains through time
- Afforestation
- Deforestation
- Degradation
- Improved forest management
- Requires a combination of remote sensing and ground measurements

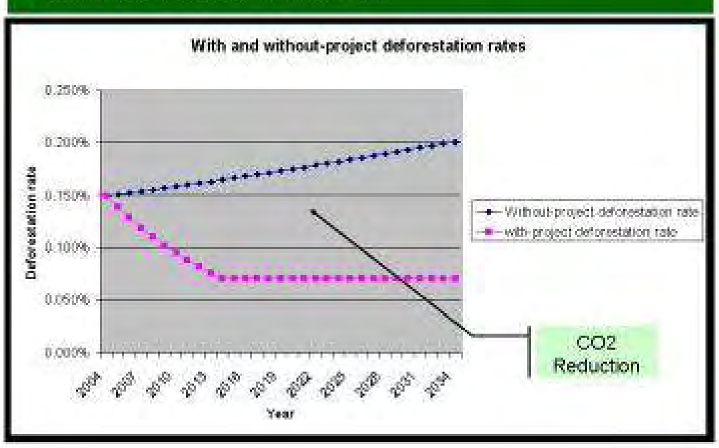
10 year sequence of land use change: natural forest to plantation

Example: Historic Baseline



Ulu Masen: Avoided deforestation scenario

Makira: Avoided deforestation scenario



History doesn't predict the future

Baseline: Concerns?

- Historic baselines may over-reward countries/actors with poor past performance
- Historic baselines difficult to establish accurately if high-quality imagery limited
- If images were taken over too short of time frame may not be accurate representation
- Projected baselines difficult to establish
- Projected baselines may exaggerate deforestation threats
- The area for inclusion in the baseline may be too narrow

History doesn't predict the future

Baseline: best practice

- Suggested best practices for setting baselines:
  - use five to ten years for more accurate historic information;
  - Re-calculate baseline each five to ten years
  - explicitly choose conservative scenario
  - indicate statistical error in baseline data;

Technical aspects of REDD

- **Leakage** - the unanticipated decrease or increase in GHG benefits outside a project's boundary as a result of project activities.
- Exists in other sectors, not just forestry
- (e.g., shifting deforestation to another area)

Leakage rates:
2 - 38%

Leakage: what is it?

- Increase in emissions in one area due to a reduction of emissions in another
- Forest conservation / avoided deforestation most prone to negative leakage

Also referred to as "Direct Leakage" Or "Activity Leakage"

Leakage: primary "Activity Leakage"

"activity shifting at local to regional scale due to release of capital and labor through project activities"

- illegal logging moves elsewhere
- palm oil concession issued in neighboring watershed

Also referred to as "In-direct Leakage" and "Market Leakage"

Leakage: secondary "Market Leakage"

"market effects at regional to global scale due to reduced supply but undiminished demand"

- increased log imports from other country

Case Study: in the region of the Pacific Northwest USA a logging moratorium in 1990s led to 85% decline in timber production off national forest
→ increased volume of Canadian imports
→ increased plantation production from Southeastern USA

Difficult to accurately quantify amount of leakage

Managing leakage

- Alternative livelihood development
  - *fruit and coffee gardens*
  - *sustainable forestry*
- Portfolio balancing
  - *reforestation*
  - *mangrove restoration*
- Improved governance and spatial planning
- Buffer credits (i.e. 10 – 40%)
- National level accounting

Technical aspects of REDD

- **Permanence** - the duration and reversibility of a reduction in GHG emissions.
- What the market desires:
  - Long-term assurance of supply and delivery of carbon credit
- In forestry carbon will be released into the atmosphere if the projects are not permanent

(con) Permanence: Losses

Everything changes, nothing stays the same

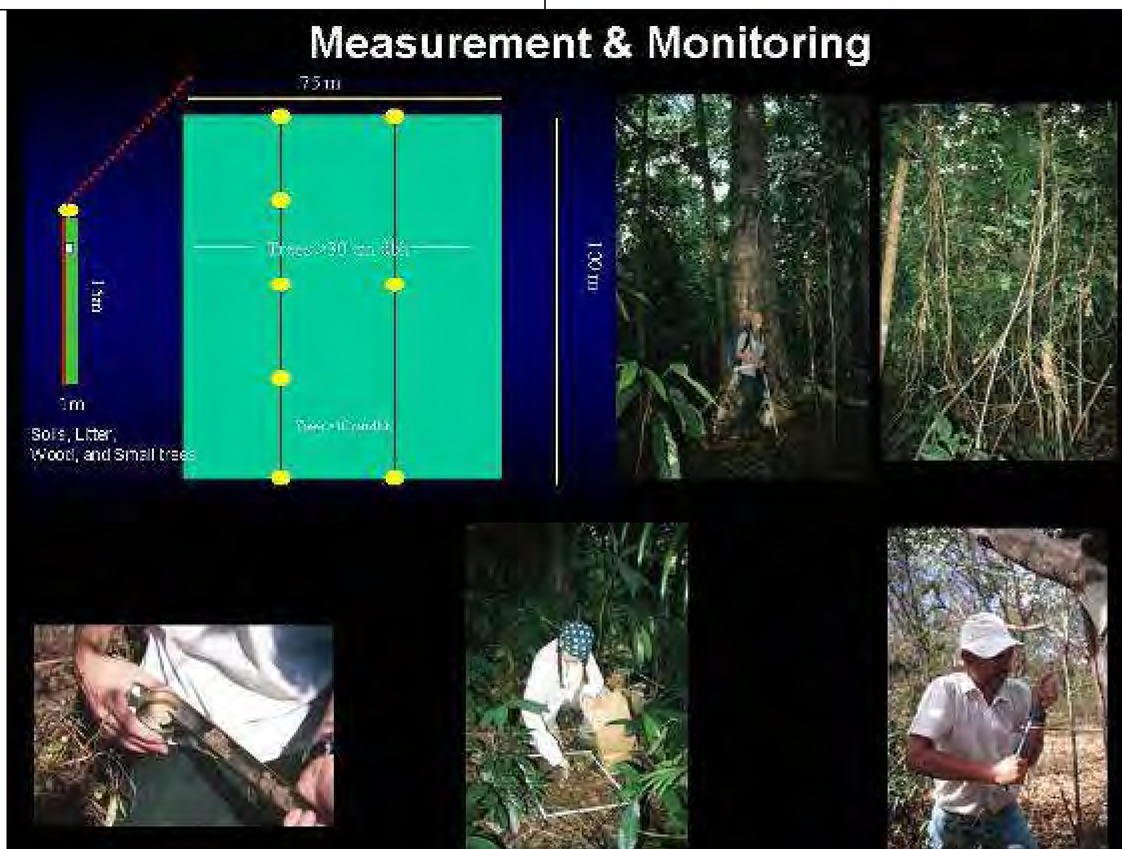
Loss due to human-caused or natural disturbances:

- Pest
- Disease
- Fire
- Wind-throw
- Trespass
- Sale
- Default
- Seizure

Managing non-permanence

Buffers of reserve credits range from 10 – 40%

- Management factors: legal, financial, tenure, staff competency, and protection
- Buffer reserves of actual carbon storage held in escrow (about 20 – 30%)
- Insurance policies (i.e. for 100 years) to pay for lost carbon
- Contracts with enforceable replacement
- Land trust (covenants)



Measurement and monitoring

In terms of C pool measurements:

- There are a number of valid methods of quantification
- There are varying degrees of precision and accuracy depending upon the degree of information needed.
- The most important objective of this workshop is insuring adequate measurement of C pools.

Measurement: IPCC Methodologies

Tier 3

- Higher level of measurement, with forest inventory systems and modelling
- Permanent sample sites and periodic measurement
- High precision disaggregated activity data

Tier 2

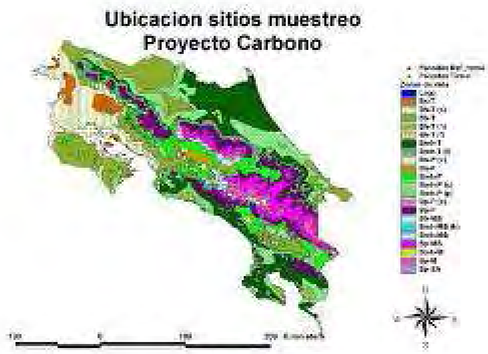
- Emission data or carbon stock data at the national or regional level
- National level emissions factors
- More precise spatial data by activity

Tier 1

- Predetermined formulas and values (e.g. for emissions factors and changes in stock)
- Data estimates for national level activities (e.g. deforestation rates, forestry statistics, vegetation cover, population changes)

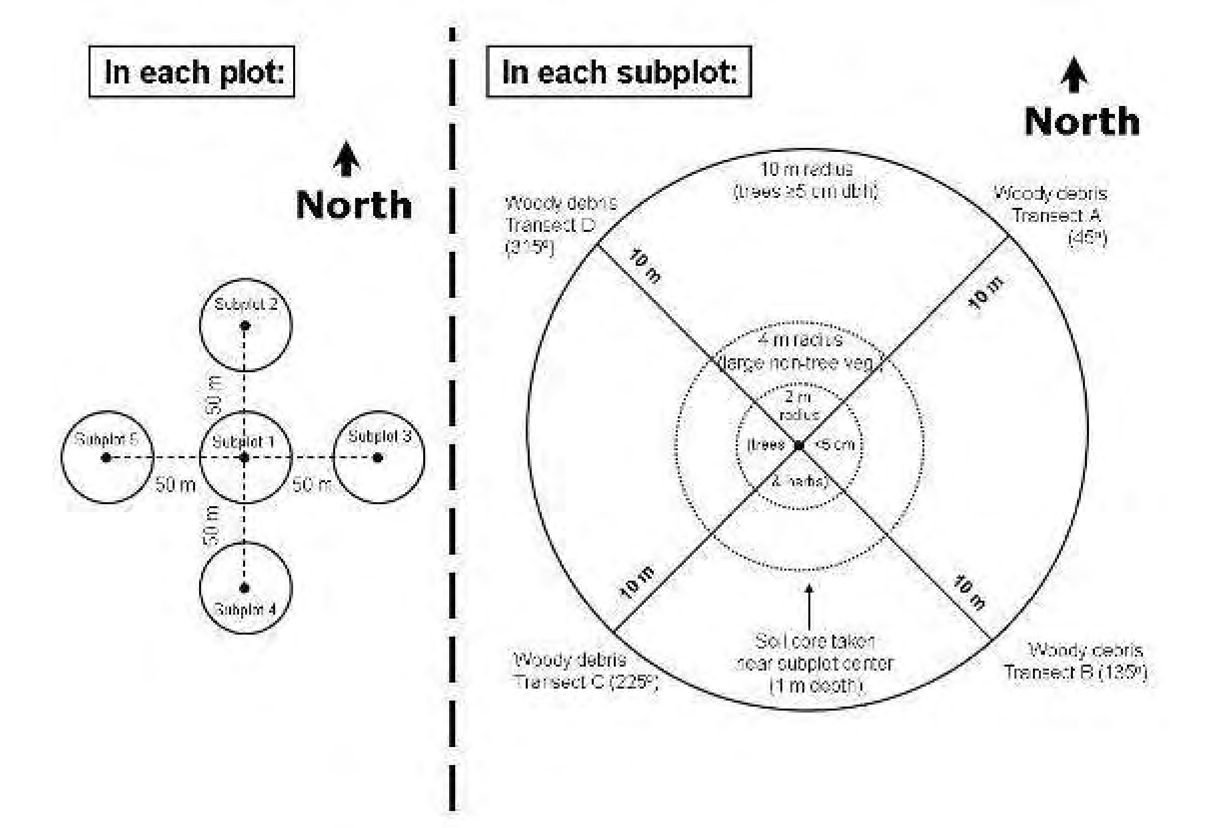
Estimating Forest Carbon Stocks

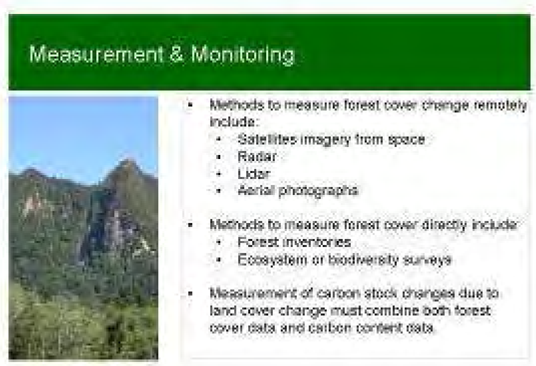
The most commonly accepted way to estimate forest carbon stocks over larger areas is to apply carbon values to broad forest classes – the 'biome-average approach' (which is an approach required by Tier 1 of the IPCC's National Greenhouse Gas Inventories).



Carbon Accounting

- Plot layout
- Sampling design
- Laboratory work
- Information management
- Analysis, interpretation
- Write-up


In each plot:
North
Subplot 2
Subplot 5
Subplot 1
Subplot 3
Subplot 4
50 m
50 m
50 m
50 m
In each subplot:
North
10 m radius
(trees ≥5 cm dbh)
Woody debris
Transect D
(315º)
Woody debris
Transect A
(45º)
10 m
10 m
4 m radius
(large non-tree veg)
2 m
radius
(trees <5 cm
& herbs)
10 m
10 m
Woody debris
Transect C (225º)
Soil core taken
near subplot center
(1 m depth)
Woody debris
Transect B (135º)


Measurement & Monitoring
Methods to measure forest cover change remotely include:
Satellites imagery from space
Radar
Lidar
Aerial photographs
Methods to measure forest cover directly include:
Forest inventories
Ecosystem or biodiversity surveys
Measurement of carbon stock changes due to land cover change must combine both forest cover data and carbon content data.

Measurement challenges

- Capabilities to measure forest biomass at national or regional scales still very limited
- Significant technological advancement in remote sensing capacity needed
- Significant ground truthing of remotely sensed imagery needed
- Carbon stocks of different forest ecosystems worldwide poorly known
- Variable data quality between countries
- Reliance on default values

Monitoring

- Monitoring of REDD at national scales will require government approved or managed monitoring programs
- These programs can (or should) be informed by existing carbon verification standards/approaches
- Monitoring at project level will conform to verification standard requirements

Monitoring and evaluation

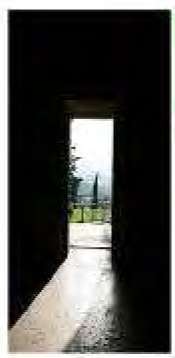
- Remote sensing of changes through time
- Resampling of field plots
- Adaptive management of the sampling approaches
- Community support – social aspects
- Fish and wildlife

Monitoring challenges

- Lack of standardized verification systems
- Internationally mandated systems may threaten national sovereignty
- Monitoring of values beyond forest carbon may overload capacity
- However, not including community impacts may see projects adversely effect indigenous peoples or poor

Thank you!

REDD Training Course



Contributors

- **Contributors to this presentation include:**
  - **Jeffrey Hayward, Rainforest Alliance Manager, Climate Initiative**

Stephen, P. 2008. Introductory Course on Reducing Emissions from Deforestation and Forest Degradation (REDD): A Training Manual. The Nature Conservancy, Conservation International, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Rainforest Alliance, and World Wildlife Fund, Inc. 99p. Available at: http://www.conservationtraining.org/

Cortez, R. and P. Stephen 2008. Introductory Course on Reducing Emissions from Deforestation and Forest Degradation (REDD): A Participant Resource Manual. The Nature Conservancy, Conservation International, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Rainforest Alliance, and World Wildlife Fund, Inc. 133p. http://www.spc.int/lrd/Climate_change/Publications/redd_participantmanual_final_2.pdf

Both available at: http://www.conserveonline.org/workspaces/trainingmaterials

PRESENTATION 2: *LAND-USE CARBON PROJECT DESIGN STANDARDS.* DR. RAM SHARMA, DCOP, IPAC PROJECT

USAID FROM THE AMERICAN PEOPLE — ipac

Certificate Training Course on Carbon Financing Project Preparation

Land-Use Carbon Project Design Standards

31 Oct. 2009

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Land-Use Projects for Climate Change Mitigation & Adaptation

Climate Change Mitigation:

- Land-use sector (e.g. forests & wetlands) provides low cost opportunities to combat climate change
- Carbon sequestration (removal & storage) of GHG by forests & wetlands as sinks
- Reduced GHG emissions (by curbing deforestation and degradation of forests & wetlands)

Climate Change Adaptation:

- Ecosystems (forests & wetlands) productivity enhancement
- Increased flow of benefits to local community through improved land-use management practices

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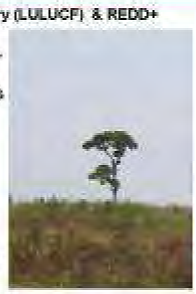
Land Use, Land Use Change & Forestry (LULUCF) & REDD+

- Chunoti Wildlife Sanctuary : Co-managed Protected Area (PA) under Nishorgo & IPAC Projects of Forest Department
- Climate Change Mitigation & Adaptation Project supporting local communities and conserving biodiversity
- Reforestation, Enrichment and Natural Regeneration of indigenous species through co-management



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Carbon Markets

- Regulatory or compliance carbon markets
  -e.g. CDM
- Voluntary carbon markets
  -e.g. Multinationals

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Carbon Offset Standards

- Standards provide a practical tool to evaluate carbon projects in the early stages of development.
- Standards enable investors and project managers to identify quality projects
- Standards help avoid implementation roadblocks and deliver their stated outcomes
- Standards help generate credible carbon offsets

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Main Carbon Offset Standards

1. Clean Development Mechanism (CDM)
   - Supported by UNFCCC parties
   - Large market share
   - Third-party verification required
2. Gold Standards
   - Supported by WWF and other environmental NGOs
   - Small market but growing
   - Third-party verification required
3. Climate, Community and Biodiversity (CCB)
   - Supported by Climate, Community and Biodiversity Alliance (CCBA)
   - Growing market
   - Third-party verification required
4. Others : Chicago Climate Change Exchange (CCX), Voluntary Carbon Standard, Voluntary Offset Standard, VER+

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Climate, Community and Biodiversity (CCB) Standards

- Suitable to evaluate land-use carbon mitigation projects that support local communities and conserve biodiversity
- CCB standards used in Chunoti Carbon Project
- CCB standards go beyond CDM requirements by generating positive community and biodiversity benefits

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CCB Standards : 15 Required Criteria & 8 Optional Criteria

- General Section (G)
  - -G1. Original conditions at project site
  - -G2. Baseline projections
  - -G3. Project design and goals
  - -G4. Management capacity
  - -G5. Land tenure
  - -G6. Legal status
  - -G7. Adaptive management for sustainability (1 Point)
  - -G8. Knowledge dissemination (1 Point)

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CCB Standards : 15 Required Criteria & 8 Optional Criteria

- Climate Section (CL)
  - -CL1. Net Positive Climate Impacts
  - -CL2. Offsite Climate Impacts ("Leakage")
  - -CL3. Climate Impact Monitoring
  - -CL4. Adapting to Climate Change and Climate Variability (1 Point)
  - -CL5. Carbon Benefits Withheld from Regulatory Markets (1 Point)

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CCB Standards : 15 Required Criteria & 8 Optional Criteria

- Community Section (CM)
  - -CM1. Net Positive Community Impacts
  - -CM2. Offsite Community Impacts
  - -CM3. Community Impact Monitoring
  - -CM4. Capacity Building
  - -CM4. Management capacity (1 Point)
  - -CM5. Best Practices in Community Involvement (1 Point)

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CCB Standards : 15 Required Criteria & 8 Optional Criteria

- Biodiversity Section (B)
  - -B1. Net Positive Biodiversity Impacts
  - -B2. Offsite Biodiversity Impacts
  - -B3. Biodiversity Impact Monitoring
  - -B4. Native Species Use (1 Point)
  - -B5. Water and soil resource enhancement (1 Point)

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CCB Standards Validation Levels

- Approved – all requirements met
- Silver – all requirements met + one point minimum from at least three different Sections
- Gold – all requirements met + six points minimum, at least one point from four different Sections

PRESENTATION 3: INTERNATIONAL AND NATIONAL CARBON MARKETS: REGULATORY AND VOLUNTARY. TODD R JOHNSON, IRG

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Global Climate Change and Carbon Financing Opportunities for Bangladesh – Phase II

International and national carbon markets: regulatory and voluntary

31 October 2009

Todd R. Johnson, IRG

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Outline of Presentation

Review of global carbon markets
- Allowance-based: EU ETS, CCX, US RGGI, NSW, NZ, Japan, others
- Project-based: compliance (CDM), voluntary (CCX, OTC), donor-driven

Compliance market - Clean Development Mechanism
- Details of market development
- Current and expected trends

Voluntary markets
- Chicago Climate Exchange – details and trends
- Over-the-Counter voluntary markets – details and trends

Donor-driven carbon financing
- World Bank carbon finance
- Other donor carbon finance

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Overview of global carbon markets: 2007-08

Market – arranged by value of transactions in 2008 (WB)	Market type	2007 volume (MtCO2e)	2007 value (MUS$)	2008 volume (MtCO2e)	2008 value (MUS$)
European Union Emission Trading Scheme (ETS)	Allowance – compulsory	2,060[1,2]	\$49,065[1] \$50,097[2]	3,093[1] 2,982[2]	\$91,910[1] \$94,972[2]
Secondary market Clean Development Mechanism	CER futures market	240[1,2]	\$5,451[1,2]	1,072[1] 623[2]	\$26,277[1] \$15,585[2]
Primary market Clean Development Mechanism	Project-based – compliance	552[1,2]	\$7,433[1] \$7,426[2]	389[1] 400[2]	\$6,519[1] \$6,118[2]
Other Kyoto mechanisms (AAUs and JI ERUs)	Allowance or project-based	41[1,2]	\$499[1,2]	39[1] 26[2]	\$505[1] \$2,557[2]
Regional markets – includes Australia, New Zealand, others	Allowance – regulated	25[1] 27[2]	\$224[1] \$238[2]	96[1] 61[2]	\$429[1] \$282[2]
Over-the-counter (OTC) [informal voluntary]	Project-based – voluntary	43[1,2]	\$263[1,2]	54[1,2]	\$387[1,2]
Chicago Climate Exchange (CCX) [formal voluntary]	Project-based – voluntary	23[1,2]	\$72[1,2]	69[1,2]	\$309[1,2]
TOTAL		2,985[1,2]	\$63,007[1] \$64,046[2]	4,811[1] 4,213[2]	\$126,346[1] \$120,189[2]

Sources:
1. [illegible]
2. [illegible]

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Review of carbon markets: Allowances (1)

European Union Emissions Trading Scheme (EU ETS)
- Largest carbon market in the world; 2/3rd of all volume in 2008 (~3 $GtCO_2e$); 72% of total value (US\$91 billion:6.34 trillion Taka)
  - ✓ Company-level cap-and-trade allowances allocated to 27 EU member states
  - ✓ Overall emissions are "capped" to create market demand for trade
  - ✓ Compulsory; compliance market – European industries must participate
  - ✓ 11,000 companies in energy-intensive industries; aviation added in 2008
- Highest average price/ton: 2007: \$24; 2008: \$31; (Feb. 09: \$10)
- Established by European Parliament in 2003; three phases:
  - ✓ Phase 1 (pilot) was 2005-2007; 95% of allowances distributed free
  - ✓ Phase 2 coincides with Kyoto 1st commitment period; target 6.5% reductions
  - ✓ Phase 3 will begin 2013-2020; auction of allowances phased over period
- **Relevance to Bangladesh**: limited; accepts CDM CERs, but not Land Use, Land Use Change, and Forestry (LULUCF) credits

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Review of carbon markets: Allowances (2)

Other allowance-based markets
- Chicago Climate Exchange: http://www.chicagoclimatex.com/
  - ✓ Trades both allowances and offsets; members committed to 6% by 2010
  - ✓ Membership consists of wide range of industries, incl. agriculture & forest
  - ✓ More later on offset trading on CCX
- Regional Greenhouse Gas Initiative: http://www.rggi.org/rggi
  - ✓ Consortium of 10 northeastern & mid-Atlantic US state governments
  - ✓ Mandatory target of 10% reduction in emissions by 2018
  - ✓ Power sector; state governments use regulations to force compliance
- New South Wales Greenhouse Gas Abatement Scheme
  - ✓ Also power sector; effectively collapsed in 2007; new CPRS underway
- New Zealand Emissions Trading Scheme (NZ ETS)
  - ✓ Struggling with legislation; now scheduled to come online in July 2010
- Japan and others – policymakers remain hesitant

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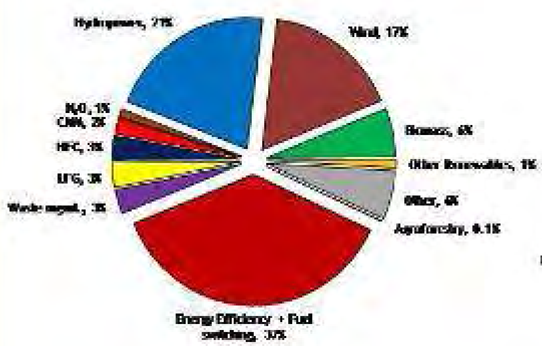
Review of carbon markets: Project-based (1)

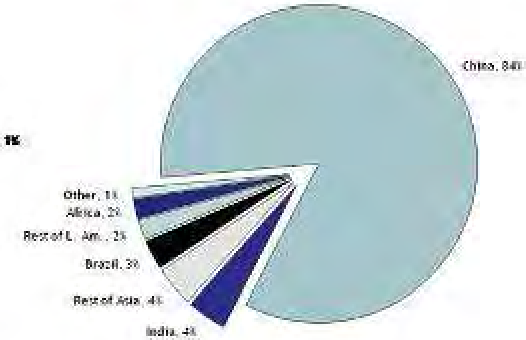
Kyoto Protocol mechanisms
- Joint Implementation (JI)
  - ✓ Only eligible activities are between Annex B (industrial) countries
  - ✓ LULUCF project for afforestation of degraded land in Romania
  - ✓ Not relevant for Bangladesh
- Clean Development Mechanism (CDM)
  - ✓ Established under Article 12 of Kyoto Protocol; operational in 2003
  - ✓ Unit of trade is Certified Emission Reduction credits (CERs)
  - ✓ Most are bought by private companies based in European Union – UK was largest buyer of credits (almost 40%) last year
  - ✓ Vast majority (84%) of projects in China; India and Brazil also strong
  - ✓ Growth steady 2003-2008, <50 $MtCO_2e$ to approx. 550 Mt in 2008
  - ✓ Secondary market in 2nd half '08 /1st half '09 more active (> 1 billion)
  - ✓ Energy efficiency, hydropower, and wind 75% of project types

Review of carbon markets: Project-based (2)

CDM PROJECTS BY TYPE - 2008; PERCENT OF VOLUME



CDM PROJECTS BY LOCATION - 2008; % OF VOLUME



Source: Capoor, K. and Ambrosi, P. (2009). *State and trends of the carbon market 2009*. Washington, DC: World Bank.

Clean Development Mechanism [CDM] (1)

What does it mean to be a "compliance" market?

- Supports country & industry compliance with Kyoto targets
- Legally-binding commitments to reduce emissions on time

What is actually being sold?

- Certified Emission Reductions (CERs)
  - ✓ Each CER represents one metric ton carbon dioxide equivalent (tCO_2e)
  - ✓ tCERs – temporary Certified Emission Reduction; address permanence
  - ✓ Voluntary Emissions Reductions (VERs) – voluntary markets (pre-CER)
- Removal Units (RMUs) from LULUCF activities like reforestation

How are they sold?

- Projects generate credits from eligible activities
- Companies buy offsets to meet compliance targets
- Markets (ETS, CCX, others) serve as trading platform

Clean Development Mechanism [CDM] (2)

What does it mean to be an "eligible activity"?

- Fits within one of the categories; for example "A/R"
- Has completed all requirements, is verified, and Board approved

What are the key requirements for eligibility of A/R projects?

- Additionality – emission reductions or removals must be those that would not happen in the absence of the project, for example
  - ✓ Document that an area was deforested prior to 1990
  - ✓ Produce a Project Design Document describing reforestation in detail
  - ✓ Carbon sequestered from reforestation generates credits that can be sold
- Permanence – activities must demonstrate that non-permanence is being addressed (for issuing of either tCERs or lCERs)
- Leakage – changes in emissions outside project area that can be attributed to the project activities

What is the full process for CDM projects?

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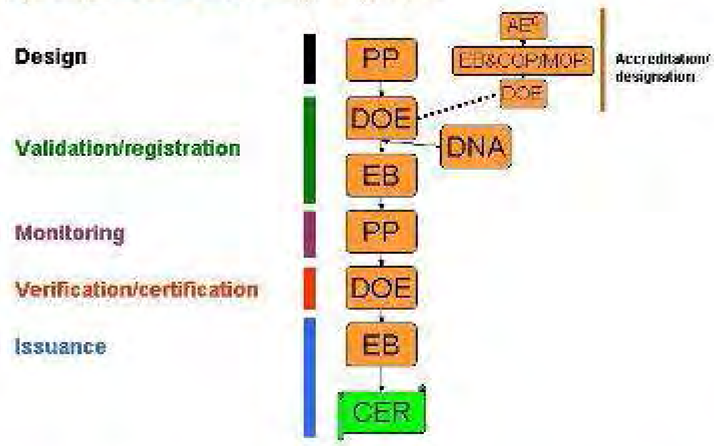
Clean Development Mechanism [CDM] (3)

CDM project activity cycle



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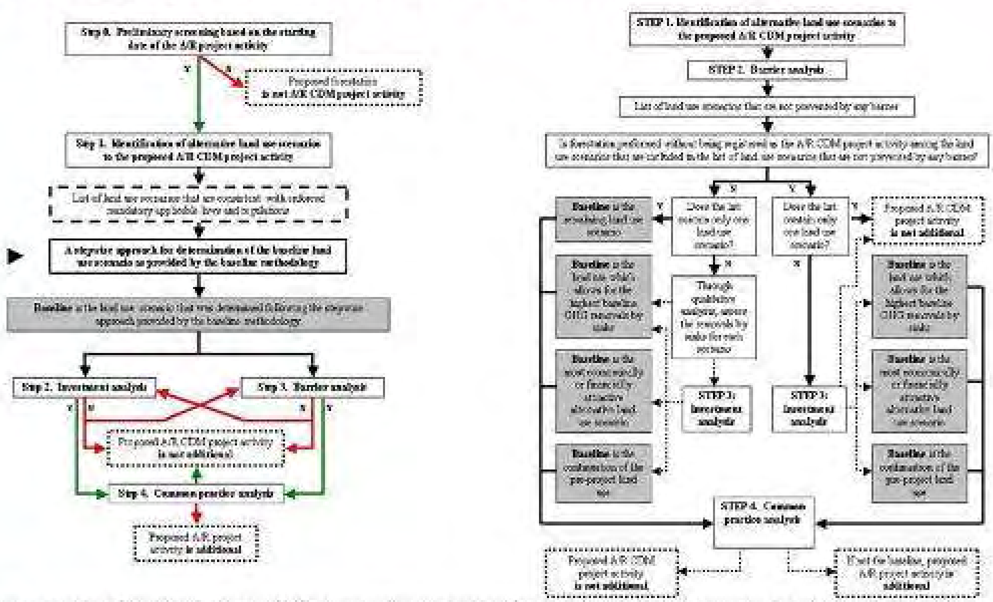
CDM (4): process for A/R additionality



Source: CDM Executive Board. (2007). Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities. EB35, Annex 19. UNFCCC

CDM (5): Summary of relevance for Bangladesh

Opportunities

- Afforestation / Reforestation sector offers promise
- Recently raised limit for Small-Scale A/R to 16 kilotons/year
- Simplified baseline and monitoring guidelines for small-scale A/R projects in agroforestry, silvopastoral, grasslands, and wetlands

Challenges

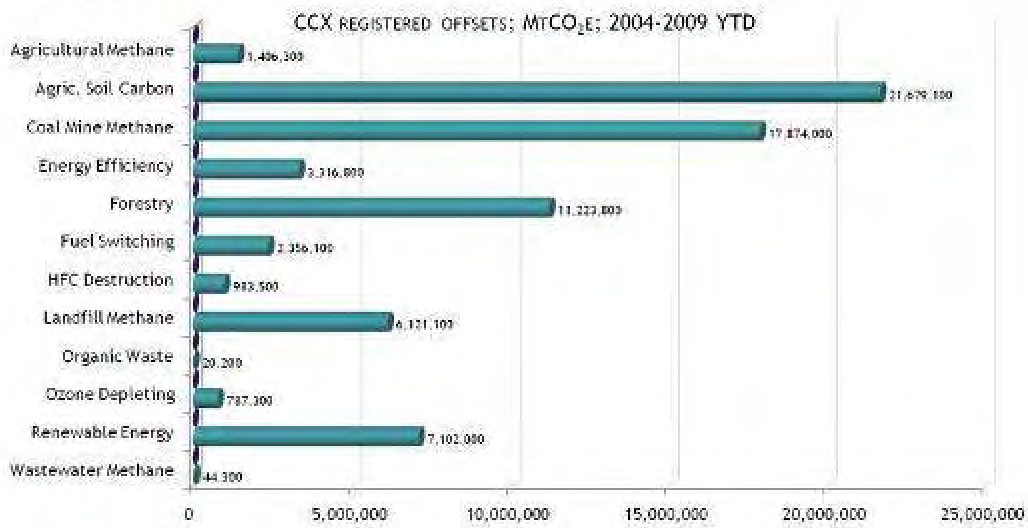
- Weak institutional capacity – public and private sector
  - ✓ Limited knowledge among some key policy decision makers (e.g., Finance)
  - ✓ Policy and legal frameworks do not facilitate project development
  - ✓ Limited institutional and technical capacity to develop projects
- CDM processes remain complicated and confusing
- High transaction costs for project development and initiation

Project-based markets: Voluntary (1)

Chicago Climate Exchange (CCX)

- Emission offset projects – what are they and what are they for?
  - ✓ Tradable credits produced by implementing mitigation projects in sectors not covered by an emissions cap
  - ✓ Must meet eligibility standards and undergo independent verification before it can be issued tradeable offsets in the Registry
  - ✓ Offset projects often produce social, economic and ecological co-benefits in addition to emissions reductions
- What are types of projects for which offsets may be issued?
  - ✓ Reforestation or other carbon sequestration in newly planted trees
  - ✓ Soil carbon capture thru best mgmt. practices on grazing land
  - ✓ Renewable energy, fuel switching, and related types of projects
  - ✓ Agricultural methane capture, or small-scale renewable biogas

Project-based markets: Voluntary (2)

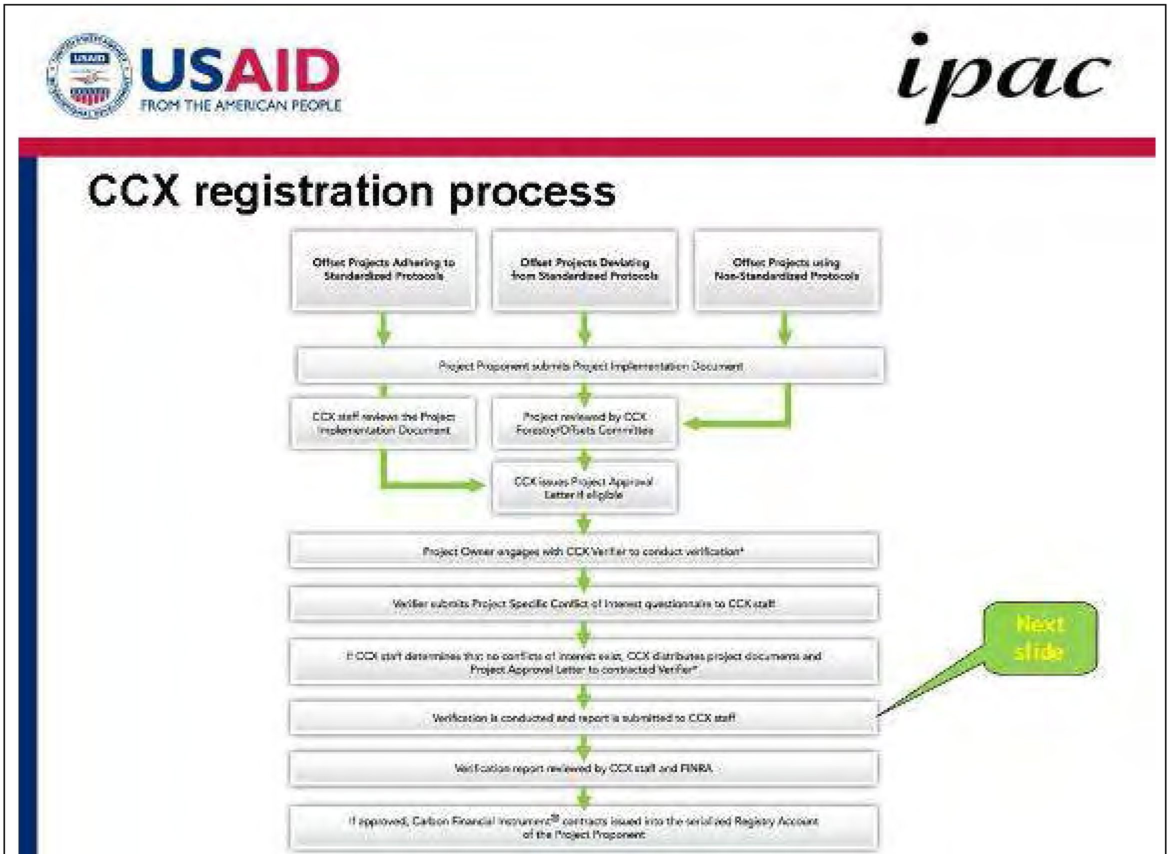


Source: http://theccx.com/docs/offsets/Reports/CCX_Offsets_Report_Vol_No4_June_Aug.pdf

Project-based markets: Voluntary (3)

CCX continued

- All CCX-registered projects must undergo 3rd party verification
- How does a project get verified?
  - ✓ CCX has a registration process for qualified verifiers
  - ✓ Each verifier must meet rigorous CCX criteria: professional capacity and experience, independent (not biased), financially stable
  - ✓ Project must pay verification fees (usually) directly to the verifier
- Can anyone sell credits to the CCX?
  - ✓ Only authorized traders can sell credits on the CCX
  - ✓ Each authorized trader has a Registry Account with the CCX
  - ✓ Anyone who claims to represent CCX or an Aggregator should be able to give you their registration number; if not, be careful!
  - ✓ A list of Members, Associate Members, and Participating Members is available on the CCX website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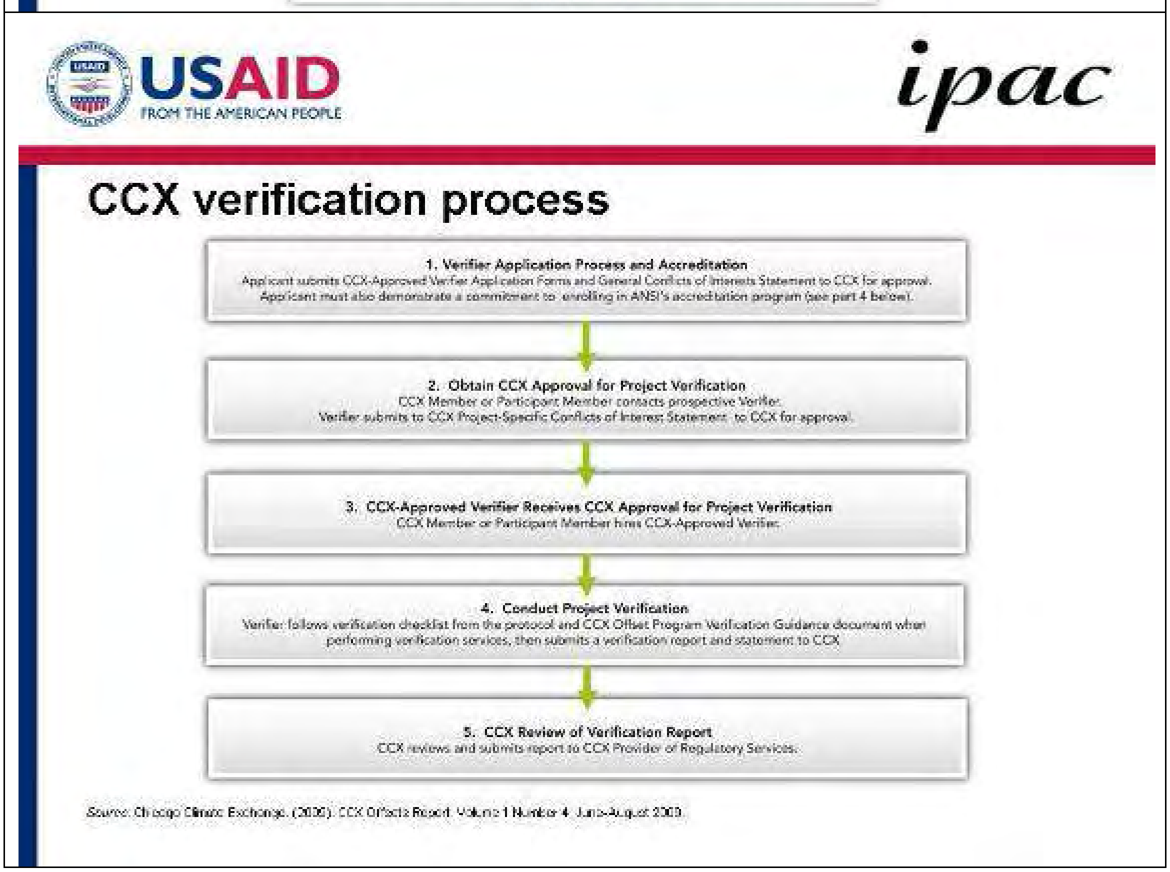
CCX registration process
Offset Projects Adhering to Standardized Protocols
Offset Projects Deviating from Standardized Protocols
Offset Projects using Non-Standardized Protocols
Project Proponent submits Project Implementation Document
CCX staff reviews the Project Implementation Document
Project reviewed by CCX Forestry/Offsets Committee
CCX issues Project Approval Letter if eligible
Project Owner engages with CCX Verifier to conduct verification*
Verifier submits Project Specific Conflict of Interest questionnaire to CCX staff
If CCX staff determines that no conflicts of interest exist, CCX distributes project documents and Project Approval Letter to contracted Verifier*
Verification is conducted and report is submitted to CCX staff
Verification report reviewed by CCX staff and FINRA
If approved, Carbon Financial Instrument® contracts issued into the serialized Registry Account of the Project Proponent
Next slide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CCX verification process
1. Verifier Application Process and Accreditation
Applicant submits CCX-Approved Verifier Application Forms and General Conflicts of Interests Statement to CCX for approval. Applicant must also demonstrate a commitment to enrolling in ANSI's accreditation program (see part 4 below).
2. Obtain CCX Approval for Project Verification
CCX Member or Participant Member contacts prospective Verifier.
Verifier submits to CCX Project-Specific Conflicts of Interest Statement to CCX for approval.
3. CCX-Approved Verifier Receives CCX Approval for Project Verification
CCX Member or Participant Member hires CCX-Approved Verifier.
4. Conduct Project Verification
Verifier follows verification checklist from the protocol and CCX Offset Program Verification Guidance document when performing verification services, then submits a verification report and statement to CCX
5. CCX Review of Verification Report
CCX reviews and submits report to CCX Provider of Regulatory Services.
Source: Chicago Climate Exchange. (2009). CCX Offsets Report. Volume 1 Number 4. June-August 2009.

Project-based markets: Voluntary (4)

CCX continued

- Some important terms
  - ✓ Carbon Financial Instrument (CFI) – the unit of trade on the CCX, each CFI is equal to 100 tCO_2e
  - ✓ Project Owner – someone who has clear legal rights to offsets from a specific CCX-registered project
  - ✓ Aggregator – someone who pools or "bundles" credits from multiple projects for trading, a list of authorized aggregators is available at http://www.chicagoclimatex.com/content.jsf?id=63
  - ✓ Bundling – pooling together several projects to lower transaction costs associated with trading credits on CCX (or OTC markets)
  - ✓ Transaction Costs – the wide range of costs that must be paid in order to develop a project and generate credits for trade
  - ✓ Registry – the electronic system for recording / trading offset credits

Project-based markets: Voluntary (6)

Summary of CCX relevance for Bangladesh

- Opportunities
  - ✓ Trading platform for either CDM-registered or voluntary projects
  - ✓ Forest carbon sequestration is approximately 15% of total volume
  - ✓ Forestry expected to grow exponentially once US has cap-and-trade
  - ✓ Transparent processes and online lists of registered participants
  - ✓ Rules-based, regulated market – low chance for fraudulent projects
- Challenges
  - ✓ As with ANY carbon financing project, the processes of developing, validating, and registering credits for trade can be intimidating
  - ✓ Contracted business transactions – requires high level of skill
  - ✓ Legal framework and policy support is weak in Bangladesh
  - ✓ Closing price 29 October 2009: 7 Taka per ton ($0.10)

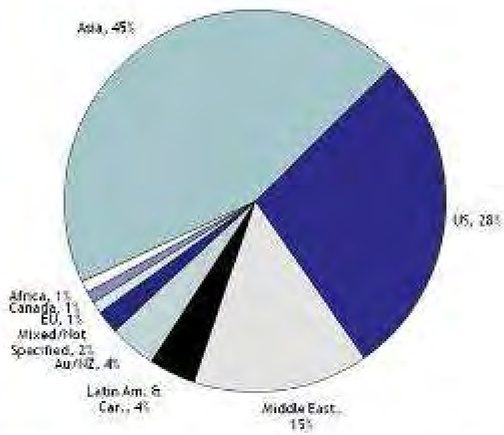
Project-based markets: Voluntary (7)

Over-the-Counter (OTC) market

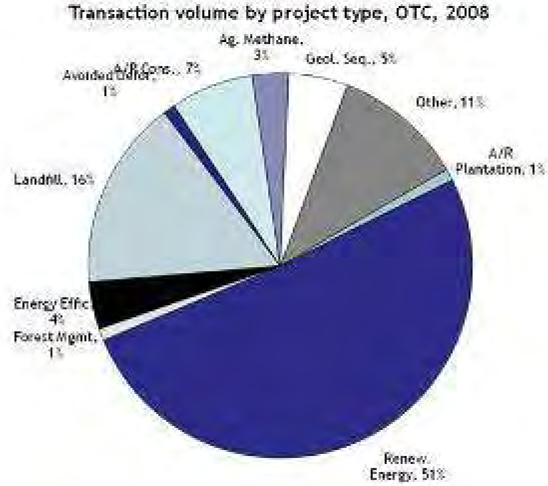
- Not one market: wide range of transactions by many players
- Called voluntary market because not subject to emissions caps
- Being outside of allowances systems, projects are carbon offsets
- Account for <3% of total volume, 0.6% of total value
- Transaction volumes and price provide indication of environment as market driver
- Aspires to be the "retirement home" of emissions, i.e., taken off resale market; 29% of all transactions in 2008
- Wide range of prices – 2008: solar averaged $22/ton; geological sequestration averaged $2.60; forest-based projects at lower end of price averages ($7.50); only agric. Soil is lower ($3.40)

Project-based markets: Voluntary (8)

Transaction Volume by Location, OTC, 2008



Transaction volume by project type, OTC, 2008



Source:
Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, T. (2009). *Fortifying the Foundation: State of the voluntary carbon markets 2009*. Washington, DC: Ecosystem Marketplace and New Carbon Finance.

Project-based markets: Voluntary (9)

Price of credits by project type, OTC, 2007/2008

Project Type	2007 price: US$ per tCO_2e	2008 price: US$ per tCO_2e
A/Reforestation - conservation	$8.20	$6.40
A/Reforestation - plantation	$6.80	$7.90
Avoided deforestation	$4.80	$6.30
Agricultural methane	$6.50	$10.0
Agricultural soil management	$3.90	$3.40
Renewable Energy - mixed source credit	$8.70	$9.60
Geological sequestration	$2.50	$2.60

Vol. of land-based credits in OTC markets, 2008

Project Type	Vol. Land-based credits ($ktCO_2e$)	Market share of total land based
Mixed Afforestation and Reforestation	646	1%
Afforestation <u>or</u> Reforestation	3,399	7%
REDD - avoided deforestation	730	1%
Improved forest management	431	1%
Agricultural soil management	267	0.5%
Other land-based projects	130	0.3%
TOTAL	**5,603**	**11%**

Source:
Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, T. (2009). *Fortifying the Foundation: State of the voluntary carbon markets 2009.* Washington, DC: Ecosystem Marketplace and New Carbon Finance.

OTC market trends observed in 2008-09 (1)

Buyers of credits

- Private sector companies: 66% of volume; private: 1%; NGO: 2%
- Overall share from individuals and NGOs is declining sharply
- 35% of purchases are for resale or investment; retirement: 29%
- Corporate social responsibility and public relations are also important reasons for purchases
- Europeans bought 53%, up from 47% in 2007, showing that the compliance markets (ETS) do not preclude voluntary market
- United States was single largest country by volume in both demand (39%) and supply (28%) for offset credits
- This may change once US has a compliance market
- Types of contracts: payment-on-delivery, unit-contingent (51%); POD, firm delivery (22%); spot transactions (18%); others (9%)

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OTC market trends observed in 2008-09 (2)

Demand for credits

- May reach 350 $MtCO_2e$ / yr by 2015, from 54 Mt in 2008 and 43 Mt in 2007
- Credit now changes hands avg 4.4 times to be retired
- Supply chain is subdivided into many actors: (table)
- Validators and verifiers now involved in 96% of all transactions

Supplier category	# suppliers 2006-08	% of total supply '08
Developer	221	35%
Broker	67	30%
Wholesaler	142	27%
Retailer	192	8%
Other	124	neg.

Simplified supply chain of OTC offset credits			
Stage 1:	Stage 2:	Stage 3:	Stage 4:
Product Creation	Product Verification / Registration	Product Distribution	Product Consumption
Project Developers	Validators / Verifiers	Wholesalers, Broker/Retail	Individuals & Institutions

Source: Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, T. (2009). *Fortifying the Foundation. State of the voluntary carbon markets 2009.* Washington, DC: Ecosystem Marketplace and New Carbon Finance.

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Standards – 27 different ones; most respected:

Voluntary Carbon Standard

- Since 2007; Climate Group/Int'l Emissions Trading Association/ World Economic Forum; roughly half of market share
- Latest standard launched '09: http://www.v-c-s.org

Gold Standard

- Non-profit foundation of 60 NGOs; managed by company APX
- Version 2 released July 2008; also linked to insurance CarbonRe

Climate Action Reserve

- Est'd. in California, positioning for US compliance market
- Has protocols for forestry, livestock methane, landfills

American Carbon Registry Standard

- Winrock Int'l. (1997); forestry standard released March 2009

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Registries – 18 total; the most important are:

American Carbon Registry (21% market share)

- Use ACR standard; managed by TZ1; 30.2 $MtCO_2e$ registered
- Charge $0.05-0.14/ton for transaction – plus validation/verification

Climate Action Reserve (11% market share)

- Uses CAR standard; managed by APX; 1.3 $MtCO_2e$ registered
- Charge $0.05/ton for transaction – plus validation/verification fee

NSW Greenhouse Gas Abatement Scheme (9% of market)

- Discussed earlier; primarily CDM or related; migrating to CPRS

Blue Registry (9% market share)

- Owned by TUV SUD; majority of credits use VER+ standard
- Fees: €0.03/t for transfer; €150/t for retirement (plus transfer fee)

Project-based markets: Voluntary (10)

Summary of OTC relevance for Bangladesh

- Opportunities
  - ✓ Wide range of buyers with specific interests in types of projects
  - ✓ Higher interest in forestry projects compared to other markets
  - ✓ Relatively (!!!) simple market access and large number of players
  - ✓ Prices can be reasonably good for high-quality carbon credits
- Challenges
  - ✓ As with ANY carbon financing project, the processes of developing, validating, and registering credits for trade can be intimidating
  - ✓ Sometimes less transparent; higher risk of fraudulent transactions
  - ✓ Legal framework and policy support is weak in Bangladesh
  - ✓ Market trend is toward same quality level as CDM, CCX, others
  - ✓ General low level of investor interest in countries such as Bangladesh that are perceived to have difficult investment climates

Donor, philanthropic, & NGO carbon financing

World Bank suite of Carbon Finance

- 12 different funds, including some for developing countries:
  - ✓ Prototype Carbon Fund: supports 24 CDM & JI projects
  - ✓ Community Development Carbon Fund: 30 projects; 3 Bangladesh
  - ✓ Biocarbon Fund: 2 tranches; closed to new project participation
  - ✓ Forest Carbon Partnership Facility: REDD-related (more later)

CarbonFund.org

- Has four forest sector projects
  - ✓ Brazil: REDD & Refor.; 3,000 ha.; 90,000 tons CO_2e; Hyundai
  - ✓ Nicaragua: Reforestation; unspecified; 170,000 tCO_2e; unspecified
  - ✓ China: Reforestation; 1,093 ha.; 170,000 tons CO_2e; unspecified
  - ✓ US (Louisiana): Refor.; unspecified; unspecified; unspecified
- Also have renewable energy, energy efficiency, and methane

World Bank Forest Carbon Partnership Facility

Specifically designed for REDD projects

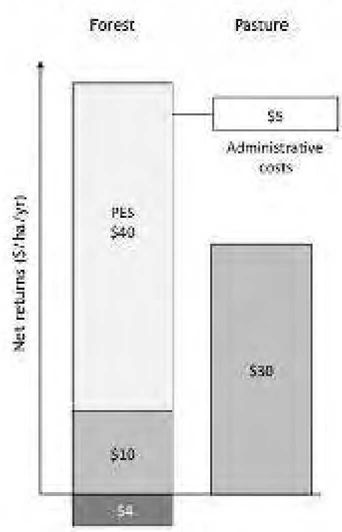
- Details still pending outcome of international negotiations
- Released draft for Readiness Preparation Proposals 23 Oct. 09
  - ✓ National readiness management and stakeholder participation
  - ✓ Prepare national REDD Strategy:
    - Land-use, forest policy, and governance relative to REDD
    - Strategy options and implementation framework for REDD
    - Assessment of social and environmental impacts of REDD
  - ✓ Develop reference scenario – REDD baseline at national level
  - ✓ Design national level REDD monitoring system
  - ✓ Schedule and budget for implementing national REDD Strategy
  - ✓ Design M&E framework for REDD program activities and national readiness process

Costs of implementing REDD

Based on WB-FCPF (April 2009)

- Stern (2007) estimated US\$1-2/tCO_2e cost to avoid deforestation in eight countries responsible for 70% of land-based emissions
- Kindermann, et al. (2008): \$10-21/tCO_2e to cut emissions 50%
- Wide range of estimates; FCPF assisting with national estimates
  - ✓ Opportunity costs – benefits of forest products; largest component
  - ✓ Implementation costs – direct & indirect costs of REDD program
  - ✓ Transaction costs – fees for legal documentation, validation and verification, project development, and especially monitoring costs
- Country costs, enterprise costs, government agency costs
- Must also consider co-benefits and costs of achieving them
- Sum of individual biome net costs across all biomes equals national cost of implementing REDD; convert to cost per ton

Indicative country-level cost of REDD program



Cost to:	Opportunity cost	Cost of implementation: Payment	Cost of implementation: Admin	Net
Government agencies		40	5	45
Individual land users	20	-40	4	-16
The country	20	0	9	29

Budgetary cost of REDD to the government:
\$40 + \$5 = \$45/ha/yr = \$0.56/tCO_2e

Cost of REDD to the land user:
(\$30-\$10) - \$40 + \$4 = -\$16/ha/yr
The land user is better off by \$16/ha/yr

Cost of REDD to the country:
(\$30-\$10) + \$9 = \$29/ha/yr = \$0.36/tCO_2e

Source: Pagiola, S. and Bosquet, E. (2009). Estimating the costs of REDD at the country level. Washington, DC: World Bank Forest Carbon Partnership Facility.

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Requirements for REDD projects – "bare bones"

Policy and legal framework to facilitate implementation

- National REDD Strategy – not strictly required but can be useful to help identify specific aspects of policy/legal environment
- Wide range of issues: resource ownership, legal status of intangible asset, contract law, financial instruments, etc., etc., etc

Establish institutions / organizations – for example, registry

Define the product – Where is the carbon? Who owns it?

How will you generate credits and how many (time frame)

Identify investor(s), validator(s), verifier(s), buyer(s), standard

Invest in project activities – begin generating credits

Sell credits through legal contract – distribute excess if any

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REDD: Summary of relevance for Bangladesh

Opportunities

- Climate benefits
  - ✓ Emissions reduced or avoided and / or carbon sequestered
  - ✓ Contribute to global solution for global problem
- Co-Benefits
  - ✓ Biodiversity & other ecosystem services; general economic dev't

Challenges

- Internal processes to facilitate capturing opportunities
  - ✓ Institutional and policy support is weak
  - ✓ Specialized skills only beginning to be developed
- External processes that may inhibit ability to capture opportunity
  - ✓ International negotiations ongoing; may not be resolved at COP-15
  - ✓ General low level of interest from investors in Bangladesh

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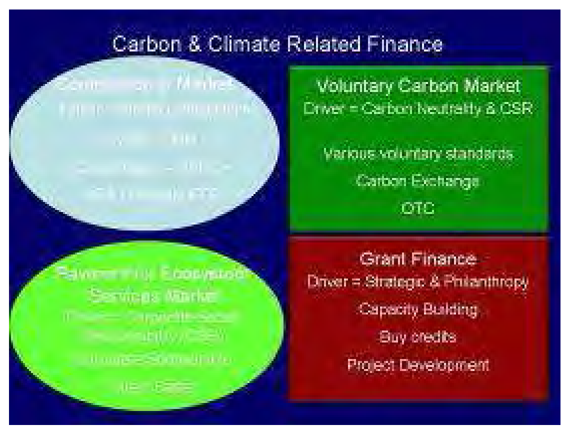
PRESENTATION 4: *THE ROLES AND VALUES OF MANGROVES: OVERVIEW OF THE INDO-PACIFIC FOREST CARBON PROJECT AND THE SUNDARBANS. J. BOONE KAUFFMAN, DANIEL DONATO, MELANIE STIDHAM, USFS*


Mangroves have strong links
to coral reef ecosystems.

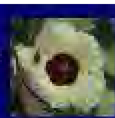

Nypa is an important source of roof thatch


501
Mangroves: important for
cultural values - ecotourism,
science, education, spiritual...


1. Mitigation
Cut greenhouse gas emissions
2. Adaptation
Learn to live with a different climate
3. Negotiation
Encourage polluting nations to act
Water Security
Soil protection
Flood protection
Food Security
Cool land surface
Forest products
Cyclone protection
Biodiversity
Scenic/tourism


Carbon & Climate Related Finance
Voluntary Carbon Market
Driver = Carbon Neutrality & CSR
Various voluntary standards
Carbon Exchange
OTC
Grant Finance
Driver = Strategic & Philanthropy
Capacity Building
Buy credits
Project Development

Values of Ecosystem Services



- Eighty percent of the world's population relies upon natural medicinal products. Of the top 150 prescription drugs used in the U.S., 118 originate from natural sources: 74 percent from plants, 18 percent from fungi, 5 percent from bacteria, and 3 percent from one vertebrate (snake species). Nine of the top 10 drugs originate from natural plant products.
- Over 100,000 different animal species - including bats, bees, flies, moths, beetles, birds, and butterflies - provide free pollination services. One third of human food comes from plants pollinated by wild pollinators. The value of pollination services from wild pollinators in the U.S. alone is estimated at four to six billion dollars per year.

Values of Mangroves

- >$300,000 Km for storm protection (Malaysia)
- $ millions fishery production ($4450/ha/yr - Australia)
- $ C values in the future (CO2 equivalents can be >4000/ha).
- The costs of good and services they provide have been estimated to be $200,000 to 900,000/ha

Gilman et al 2008

Threats to ecosystem services

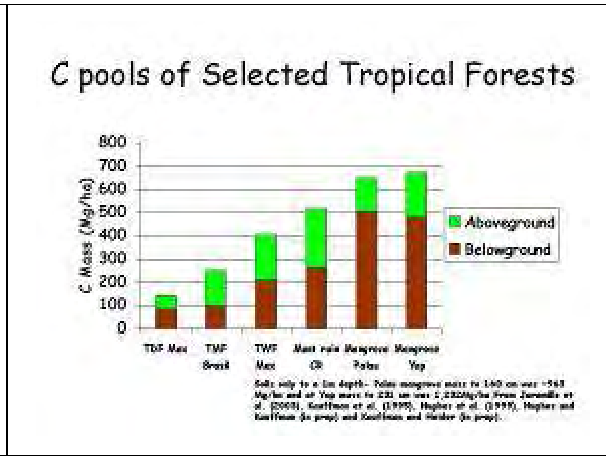
- Land Use activities that do not value the sustainability of ecosystem services
- Global Climate change

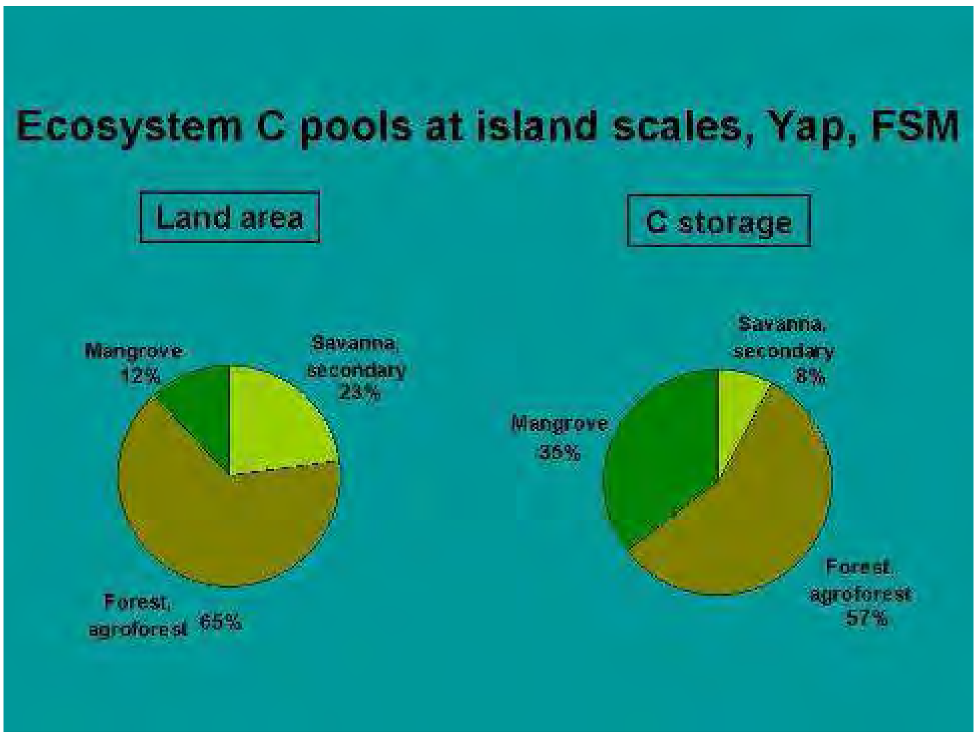
Many human activities disrupt, impair, or reengineer ecosystems every day including:

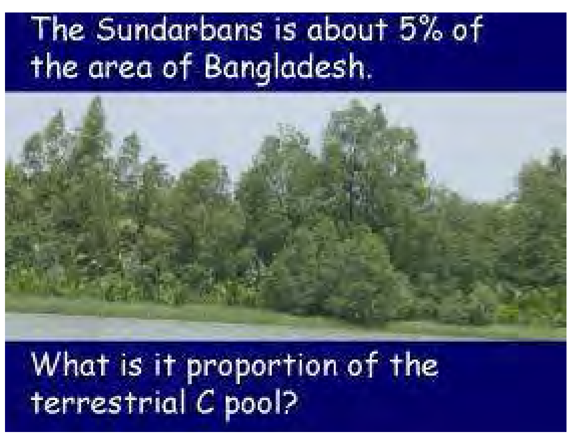
- runoff of pesticides, fertilizers, and animal wastes
- pollution of land, water, and air resources
- introduction of non-native species
- over harvesting fisheries
- destruction of wetlands
- erosion of soils
- deforestation
- urban sprawl

While mangroves are adapted to life at the land/ocean interface and disturbances such as typhoons, tsunamis, etc they are greatly threatened by land use/land cover change as well as the results of global climate change


Among the largest forest C pools on earth are found in forests of the Indo-Pacific - freshwater swamp (peat) forests and mangroves
• Swamp forests - large trees coupled with organic soils as deep as 6m
• Mangroves - high above ground biomass with organic (peats/mucks) often exceeding 2-3m in depth


C pools of Selected Tropical Forests
C Mass (Mg/ha)
800
700
600
500
400
300
200
100
0
Aboveground
Belowground
TDF Mex
TWF Brazil
TWF Mex
Mangrove Palau
Mangrove Yap


Ecosystem C pools at island scales, Yap, FSM
Land area
C storage
Mangrove 12%
Savanna, secondary 23%
Forest, agroforest 65%
Savanna, secondary 8%
Mangrove 35%
Forest, agroforest 57%


The Sundarbans is about 5% of the area of Bangladesh.
What is it proportion of the terrestrial C pool?

What is the relative impact of different GHG's?

-Depends on how long they stay in the atmosphere and how good they are at absorbing infrared heat

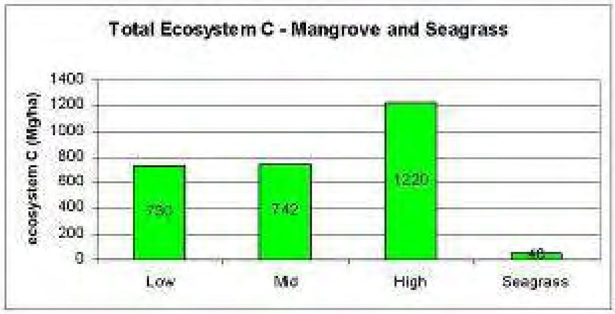
Greenhouse Gas	Atmospheric Lifetime (yrs)	Global warming potential (CO_2 equivalent)
Carbon dioxide (CO_2)	Variable (5-2000)	(1)
Methane (CH_4)	12	23
Nitrous oxide (N_2O)	114	296
Hydrofluorocarbons (HFCs)	260	120 – 12,000
Perfluorocarbons (PFCs)	10,000 (C_2F_6)	5,700 – 11,900
Sulphur hexafluoride (SF_6)	3,200	22,200

This means that:

- 1 t CH_4 has the equivalent effect of 23 tons of CO_2
- 1 t N_2O has the equivalent effect of 296 tons of CO_2

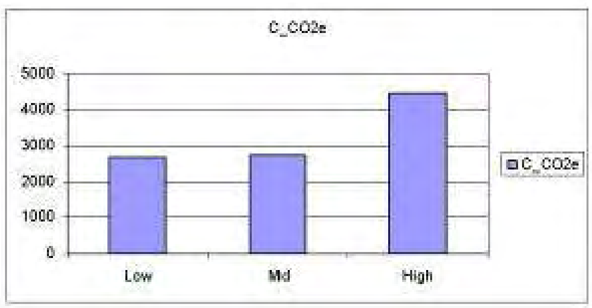
What human activities generate GHGs?

Greenhouse Gas	Industrial Sources	Land Use Sources
Carbon dioxide (CO_2)	fossil fuel combustion and cement manufacturing	Deforestation and burning of forests
Methane (CH_4)	Landfills, coal mining, natural gas production	Conversion of wetlands Rice paddies Livestock production
Nitrous oxide (N_2O)	Fossil fuel combustion Nitric acid production	Fertilizer use Burning of biomass
Hydrofluorocarbons (HFCs)	Industrial processes Manufacturing	---
Perfluorocarbons (PFCs)	Industrial processes Manufacturing	---
Sulphur hexafluoride (SF_6)	Electrical transmission and distribution systems	----

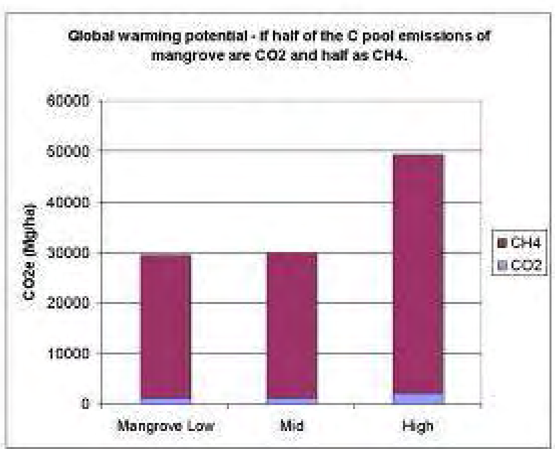


Land use/ land cover change in mangrove will result in a much greater loss of ecosystem C than in upland ecosystems on mineral soil

Draft CO2 equivalents – Runnuw mangrove, Yap



C to CO2e mult x 3.67 (none to CH4, conservative)



The GWP (CO2 equivalence) of methane is 21 (IPCC 2005)

Implications

- C pools of mangrove and peat forests are among the largest ecosystem C pools in the tropics
- The quantity of C susceptible to loss due to land cover change and global climate change is inherently greater than in upland forests
- If true, the CO_2 equivalence (global warming potential) of mangrove & peat forest ecosystems may very well be the highest in the world.
- The unique features and ecosystem services of mangroves and peat forests make them especially valuable as sites for REDD strategies

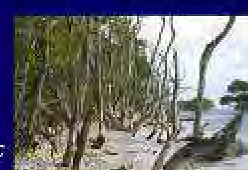
Climate Change effects on Mangrove

- Sea level rise
- Changes in high water events – typhoons
- ENSO events
- Atmospheric CO2 conc.
- Ocean circulation patterns
- Health of functionally linked neighboring ecosystems
- Human responses to climate change

Gilman et al 2008

Potential impacts of climate change resulting the degradation or loss of mangroves

- Threats to human safety and shoreline development - loss of flooding, storm wave protection
- Reduce coastal water quality
- Reduce biodiversity
- Eliminate fish and crustacean nursery habitat
- Loss of commodities - wood, food, shelter
- Release large quantities of stored C and thereby exacerbate global climate change



Mangrove vulnerability

Most vulnerable –

- Low relief islands
- Lack of rivers
- Carbonate settings
- Mangroves blocked by coastal development or steep topography
- Mangroves already stressed by human uses

McLeod and Salm 2006

Mangrove vulnerability

- Least Vulnerable
  - Mangroves on deep sediments on high islands
  - Riverine mangroves
  - Mangroves with room to move inland
  - Mangroves in remote areas
  - Mangrove surrounded by flourishing dense mangroves
  - Mangroves with little human stressors

McLeod and Salm 2006

Sundarbans characteristics

<u>Increases resistance</u>

- Riverine
- Deep sediments
- Surrounded by dense forests

<u>Increases vulnerability</u>

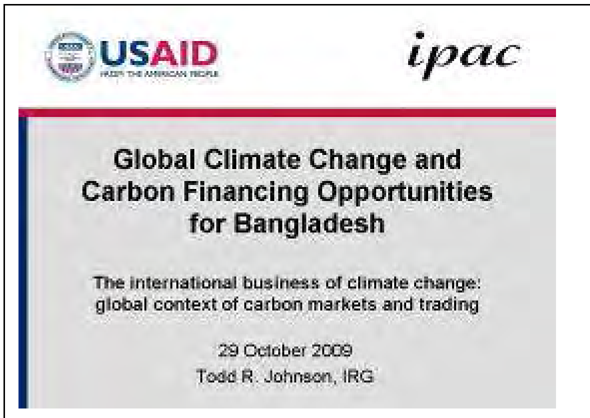
- Strong human pressures
- Up stream threats to water quality and delivery
- Unable to move inland with sea level rise

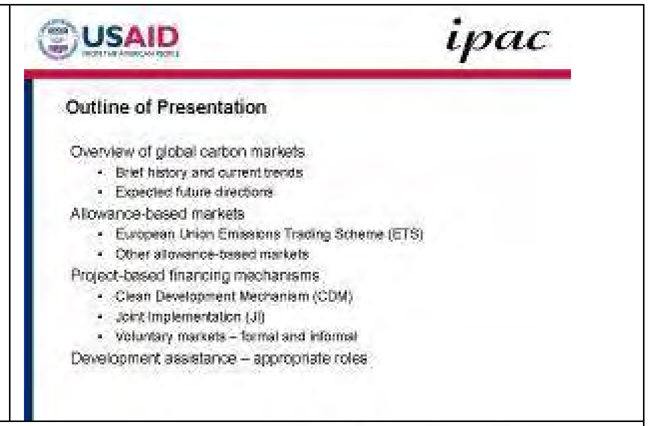
Strategies to promote resilience

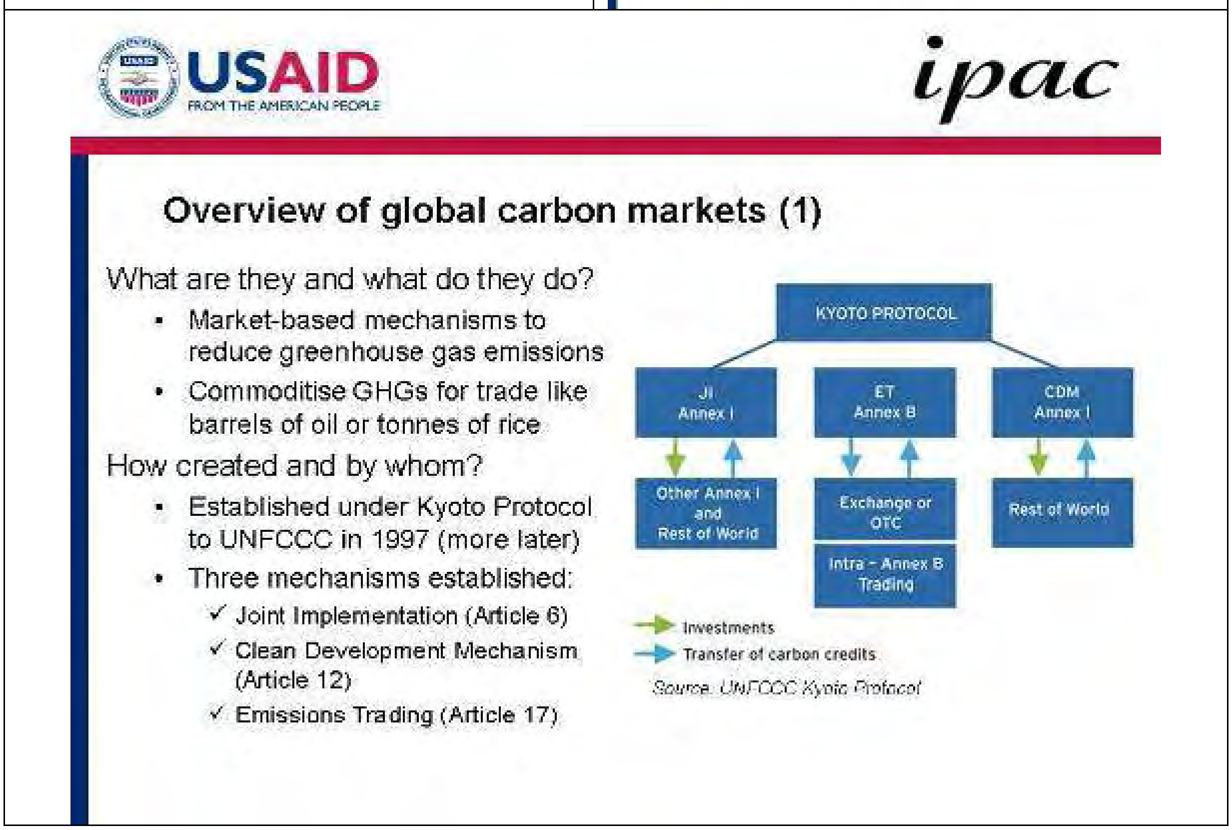
- Apply risk-spreading strategies to address uncertainties in climate change
- Id and protect critical areas
- Manage human stresses on mangroves
- Est buffer zones to allow mangrove migration in response to sea level rise
- Restore degraded areas
- Understand and preserve connectivity with upstream and marine habitiats (freshwater, sediments, sea grass and coral reefs)
- Establish baseline data and monitor response to climate change
- Implement adaptive strategies
- Develop alternative livelihoods for mangrove dependent communities as a means to reduce mangrove destruction
- Build partnerships with a variety of stakeholders to generate finances and support to respond to the impacts of climate change

McLeod and Salm 2006

PRESENTATION 5: *THE INTERNATIONAL BUSINESS OF CLIMATE CHANGE: GLOBAL CONTEXT OF CARBON MARKETS AND TRADING.* TODD R JOHNSON, IRG







Overview of global carbon markets (2)

How do you commoditise an atmospheric gas?

- Measured in units of carbon dioxide equivalent (CO_2e), expressed in metric tonnes to be able to standardize – similar to selling oil in barrels
- Other GHGs expressed in CO_2e based on contribution to global warming measured over 100 yrs.:

Greenhouse Gas	Chemical Symbol	CO_2e
Methane	CH_4	[illegible]
Nitrous Oxide	N_2O	[illegible]
Sulfur Hexafluoride	SF_6	[illegible]

What is actually being sold?

- Assigned Amount Units (AAUs) for Annex B countries – measure of allowed emissions under first commitment period of Kyoto (2008-2012)
- Certified Emission Reductions (CERs) from CDM projects
- Emission Reduction Units (ERUs) from JI projects
- Removal Units (RMUs) from LULUCF activities such as reforestation
- Voluntary Emissions Reductions (VERs) – voluntary markets (pre-CER)

Overview of global carbon markets (3)

Market – arranged by value of transactions in 2008 (WB)	Market type	2007 volume ($MtCO_2e$)	2007 value (M$US)	2008 volume ($MtCO_2e$)	2008 value (M$US)
European Union Emission Trading Scheme (ETS)	Allowance - compulsory	2,060[1,2]	$49,065[1] $50,097[2]	3,093[1] 2,982[2]	$91,910[1] $94,972[2]
Secondary market Clean Development Mechanism	CER futures market	240[1,2]	$5,451[1,2]	1,072[1] 623[2]	$26,277[1] $15,585[2]
Primary market Clean Development Mechanism	Project-based – compliance	552[1,2]	$7,433[1] $7,426[2]	389[1] 400[2]	$6,519[1] $6,118[2]
Other Kyoto mechanisms (AAUs and JI ERUs)	Allowance or project-based	41[1,2]	$499[1,2]	38[1] 24[2]	$505[1] $2,517[2]
Regional markets – includes Australia, New Zealand, others	Allowance - regulated	25[1] 27[2]	$224[1] $238[2]	96[1] 61[2]	$429[1] $292[2]
Over-the-counter (OTC) [informal voluntary]	Project-based – voluntary	43[1,2]	$263[1,2]	54[1,2]	$397[1,2]
Chicago Climate Exchange (CCX) [formal voluntary]	Project-based – voluntary	23[1,2]	$72[1,2]	69[1,2]	$309[1,2]
TOTAL		2,985[1,2]	$63,007[1] $64,046[2]	4,811[1] 4,213[2]	$126,346[1] $120,189[2]

Sources:
1. Capoor, K. and Ambrosi, P. (2009). *State and trends of the carbon market 2009*. Washington, DC: World Bank
2. Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, T. (2009). *Fortifying the Foundation: State of the voluntary carbon markets 2009*. Washington, DC: Ecosystem Marketplace and New Carbon Finance.

Allowance markets

European Union Emission Trading Scheme

- Established by European Parliament in 2003 as mechanism for trading in allowable emissions according to Kyoto commitments – allocated by industry in each member state according to historic emissions levels
- By far the most important at this stage in carbon market development
  - ✓ Accounted for 64% of total volume and 73% of total value in 2008
  - ✓ Average price of different vintages over past months €15 (US$22.50)
  - ✓ Experienced 87% year-on-year growth, measured in value terms, over 2007
- Recession hit hard but growth continued despite volatility
  - ✓ Price in July 2008 was nearly double that of July 2009
  - ✓ Some of late-2008, early 2009 volume was sales of credits obtained free from EU
  - ✓ Plans to have full auction may now be postponed due to effects of recession

Other Allowance markets

- Australia and New Zealand have functioning (sort of) but small markets
- Japan and US are still thinking about it; local US markets are interesting

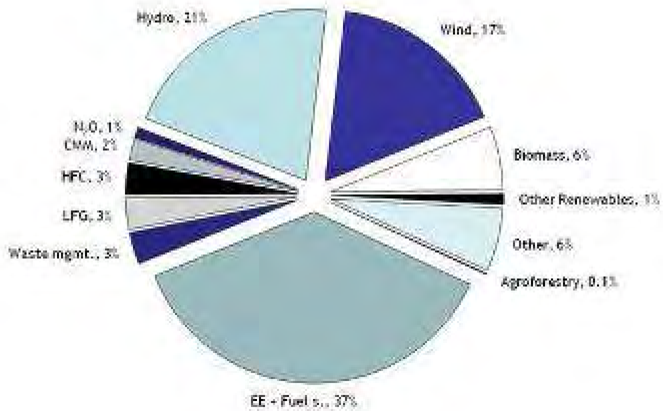
Project-based markets (1)

Kyoto mechanisms

- Clean Development Mechanism (CDM)
  - ✓ Established under Article 12 of Kyoto Protocol; became operational in 2000
  - ✓ Most Certified Emission Reduction credits (CERs) are bought by private companies based in European Union – UK was largest buyer of credits (almost 40%) last year
  - ✓ Vast majority (84%) of projects to date have been in China, India and Brazil (strong)
  - ✓ Growth was steady 2003-2008, from <50 $MtCO_2e$ to approximately 550 Mt in '08
  - ✓ Secondary market emerged in 2nd half '08 and 1st half '09 as more active (>1 billion)
  - ✓ Energy efficiency, hydropower, and wind account for 75% of project types
- Joint Implementation (JI) mechanism
  - ✓ Established under Article 6 of Kyoto Protocol; became operational in 2000
  - ✓ Emission Reduction Units (ERUs) issued only from beginning 2008
  - ✓ Only eligible activities are between two Annex B countries (industrial economies)
  - ✓ Russia has 68% market share of projects; Ukraine 10% as of March 2009
  - ✓ Only LULUCF projects for afforestation of degraded agricultural land in Romania

Project-based markets (2)

CDM projects by type - 2008; percent of volume



Source:
Capoor, K. and Ambrosi, P. (2008). *State and trends of the carbon market 2008*. Washington DC: World Bank.

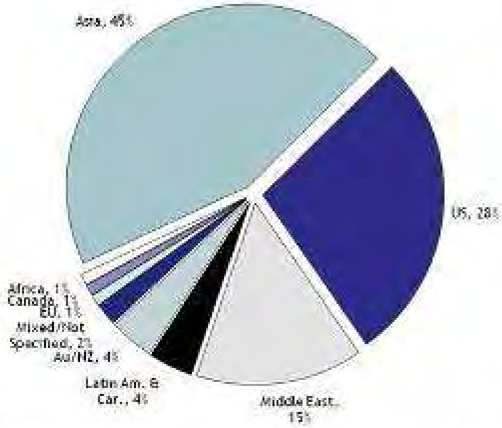
Project-based markets (3)

Voluntary markets

- Chicago Climate Exchange (CCX) – formal, regulated
  - ✓ Voluntary (not compulsory), membership-based network of markets; since
  - ✓ World's first legally binding system for "cap and trade" emissions reductions
  - ✓ Set up along lines similar to Kyoto mechanisms; rules based, regulated by CFTC
  - ✓ Trade units: CCX Carbon Financial Instruments (CFIs) = 100 tCO_2e; also traded: RGGI allowances, CDM CERs, Climate Registry's Climate Reserve Tons (CRTs)
  - ✓ Growth strong from very small base: 2 Mt in 2004 to 69 Mt in 2008 (<1.5% of total)
  - ✓ Price on Tuesday: US$0.10 (less than 7 Taka) per tonne; has been low for months
- Over-the-Counter (OTC) market – informal, unregulated
  - ✓ Not one market; rather, a wide range of transactions not under emissions caps
  - ✓ Because it is outside of allowances systems; all projects are for carbon offsets
  - ✓ Account for <3% of total volume, 0.6% of total value of world carbon markets
  - ✓ Aspires to be the "retirement home" of emissions; i.e., taken off resale market
  - ✓ Transaction volumes and price provide indication of environment as market driver

Project-based markets (4)

Transaction Volume by Location, OTC, 2008



Land-based credits sold in OTC markets, 2008

Project Type	Vol. Land-based credits (ktCO$_2$e)	Market share of total land-based
Mixed Afforestation and Reforestation	646	1%
Afforestation or Reforestation	3,399	7%
REDD - avoided deforestation	730	1%
Improved forest management	431	1%
Agricultural soil management	267	0.5%
Other land-based projects	130	0.3%
TOTAL	5,603	11%

Source:
Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, T. (2009). *Fortifying the Foundation: State of the voluntary carbon markets 2009.* Washington, DC: Ecosystem Marketplace and New Carbon Finance.

Ongoing dynamics – markets meet politics

Biggest players engaging
- United States
  - ✓ Environmental Protection Agency (EPA) asserted authority to regulate C "pollution"
  - ✓ Waxman-Markey bill (H.R. 2454) passed House of Representatives June 2009
  - ✓ Kerry-Boxer bill introduced in Senate last month; hearings to begin in November
  - ✓ Consensus around "cap and trade" rather than carbon tax or other mechanisms
  - ✓ Highly affected industries pushing back hard with various lobbying campaigns
  - ✓ Bottom line is that Administration is willing, Congress less certain to pass legislation
- China
  - ✓ Officially became largest emitter in latest IPCC Assessment Report
  - ✓ Heavily engaged using CDM funding to transform energy sector away from coal
  - ✓ Continued resistance to efforts to place themselves under emissions cap
  - ✓ Prefer limiting per capita emissions, untenable to others (except perhaps India)
  - ✓ Reported to be working informally on reaching viable consensus by Copenhagen

Possible future trends – speculative "best guesses"

Reduced Emissions from Deforestation & Forest Degradation (REDD+)
- Perhaps furthest developed mechanism for agreement in Copenhagen
- Would allow countries to sell stored carbon on markets, IF verified eligible
- Attempting to address shortcomings of CDM for terrestrial carbon projects
- Methodological issues remain – permanence, leakage, accounting rules
- Perhaps biggest impediments are related to institutional capacity at all levels

Agricultural, rangeland, and wetlands soil carbon
- Much less consensus but lots of interesting research on how it may be done
- World Bank and others optimistic; many thorny issues and challenges remain
- Again linked to tenure systems, legal frameworks, livelihood & rights issues
- Likely remain niche voluntary market for foreseeable future – "guilt carbon"
- REDD processes being watched closely as possible model for formal adoption

Official development assistance – potential roles?

Project development costs
- Markets interested in products for sale, not community organizing costs
- Significant up-front transaction costs e.g., inventory, packaging, etc.

Build institutional capacity
- Carbon accounting methodology within relevant entities
- Land, tree, and especially carbon tenure systems, legal frameworks
- Carbon registry, standards organization, 3rd party auditors

Buy down risk
- Investor confidence levels low; similar to other types of FDI
- Creative use of credit guarantees, other mechanisms may alleviate

Optimize co-benefits
- Broader development objectives unlikely to be subsidized by C markets
- Co-benefits can be substantial, yet unrecognized in Convention

THANK YOU!

PRESENTATION 6: BENEFITS DISTRIBUTION AND COST BENEFIT ANALYSIS OF A LAND-USE CARBON PROJECT. DR. RAM SHARMA, DCOP, IPAC PROJECT

USAID | ipac

Certificate Training Course on Carbon Financing Project Preparation

Benefits Distribution and Cost Benefit Analysis of a Land-Use Carbon Project

1 Nov. 2009

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Why Cost Benefit Analyses?

- Helps identify benefits stream
- Helps identify costs stream
- Helps identify equitable distribution of benefits
- Requirement of donors, particularly multilateral Development Banks
- Requirement of National Agencies (e.g. TPP and DPP)
- Others??

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Costs Stream : A Case Study of Chunoti

- Implementation of Reforestation technologies including nursery development and reforestation

  - Plantations (at 2m x 2m) @Tk. 28,000/- (may need upward revision now)

  - Enrichment plantations with natural regeneration management : @ Tk. 14,000/- and @ Tk. 10,000/-

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Costs Stream : A Case Study of Chunoti

- Establishment (staff, etc.) cost
- Revolving Fund
- Costs for conservation-linked micro-enterprises and other income generation activities
- Monitoring Expenses
- Technical Assistance
- Others including service charges

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Benefits Stream

- Identification of applicable benefits stream including both quantitative and qualitative benefits accruing from a carbon project implementation
- Tangible benefits that can be monetized
- Intangible benefits that can be identified but cannot be monetized in the absence suitable economic methods
- Timeline of the benefits accruing from the project implementation
- Equitability and impacts on different strata of local community
- Intermittant benefits (e.g. thinning, NTFPs) accruing regularly are preferable than one time final harvest final felling at maturity)

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Identifying Externalities

- Land-based projects can have many externalities that need to be identified
- Environmental externalities (global climate change)
- Socio-economic externalities
- Global Public Goods
- Internalization of the identified externalities
- Valuing of selected externalities
- Identification of different groups impacted by externalities

Cost Benefit Analyses

- Financial Cost Benefit Analysis (based on market prices)
- Economic Cost Benefit Analysis (based on opportunity cost)
- Social Cost Benefit Analysis (based on social shadow pricing)

Cost Benefit Analysis Criteria/Tools

- Net Present Value (NPV)
- Cost Benefit Ratio (CBR)
- Internal Rate of Return
- Shadow Pricing

- THANKS

PRESENTATION 7: LAND TENURE AND LAND-USE CARBON PROJECT MANAGEMENT IN BANGLADESH. DR. RAM SHARMA, DCOP, IPAC PROJECT

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Certificate Training Course on Carbon Financing Project Preparation

Land Tenure and Land-Use Carbon Project Management in Bangladesh

1 Nov. 2009

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Land Tenure in Bangladesh

- Forest Land
- Public (Khas) Land
- Private Land
- Governance – How project related decisions are made and implemented locally
- Community Owned Land (??)

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Forest Land

- Reserved Forest (RF) under the Forest Act, 1927
- Protected Forest (PF) under the Forest Act, 1927
- Others
- Unclassed State Forests (USF) as *khas* land under Ministry of Land
- Many natural forests in Bangladesh are mosaics of land-uses including private lands as patches

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Wetlands

- Wetlands as *khas* land
- Wetlands within Forestland
- Private waterbodies including *pukurs*
- Others (???)

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Land Tenure Issues

- No significant land tenure disputes in the project area
- Project should fundamentally help to resolve tenure issues
- Project will not encroach private or government property
- Project response to potential in-migration (if any) of people from surrounding areas

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Legal Issues

- Project based on sound legal framework
- Project based on applicable planning and regulatory requirements
- Project is approved by appropriate authorities including DNA

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Issues related to local indigenous community

- Any infringement of the rights and customary practices of local indigenous community
- Gainful involvement of local indigenous community
- Others

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Important questions to ponder

- Who is legal owner of the land on which the project will be implemented?
- Who is authorised to sign MOU and other contracts?
- Both surface and underground natural resources are involved in carbon estimation
- Ministries/Govt. Organizations responsible for on-ground and under-ground natural resources and applicable rights

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Carbon Project Management

- The success of a carbon project will greatly depend on its proper management
- Technically competent and experienced team for project implementation
- Gainful involvement of local key stakeholders
- Management capacity is appropriate
- Roles and responsibilities of participating institutions are well defined
- Adequate financial resources and procedures

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Proposed Management Structure for Chunoti Project

- Forest Department being technical organization will implement technical interventions including reforestation technologies
- Co-management Committees (CMCs) managing CPGs and operating Revolving Fund
- Local NGO implementing social mobilization activities including conservation-linked alternative income generation activities and micro-enterprise

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Proposed Management Structure for Chunoti Project

- Gtz providing technical assistance
- Arannayk Foundation helping in funds flow

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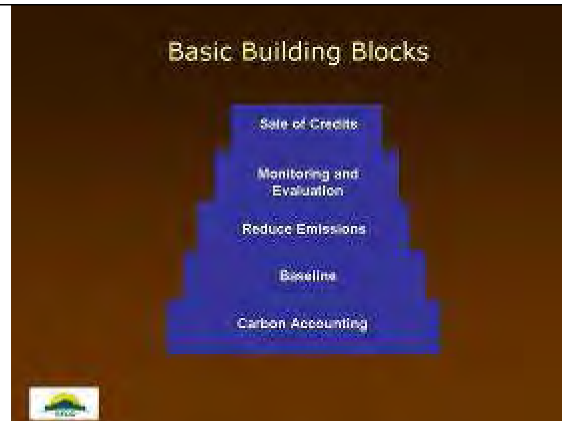
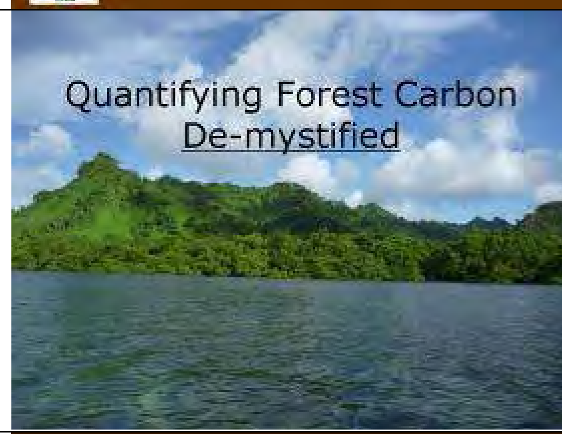
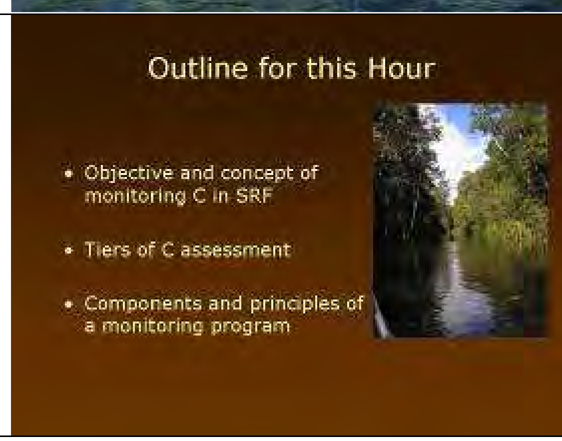
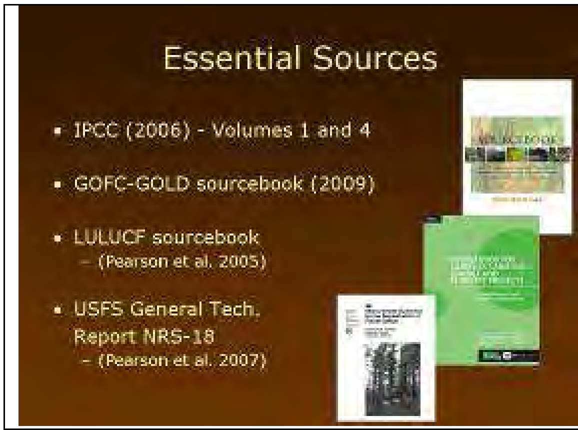
THANKS

PRESENTATION 8: APPLYING INTERNATIONAL STANDARDS AT THE PROJECT LEVEL. D.C. DONATO, M.A. STIDHAM, J.B. KAUFFMAN, USFS

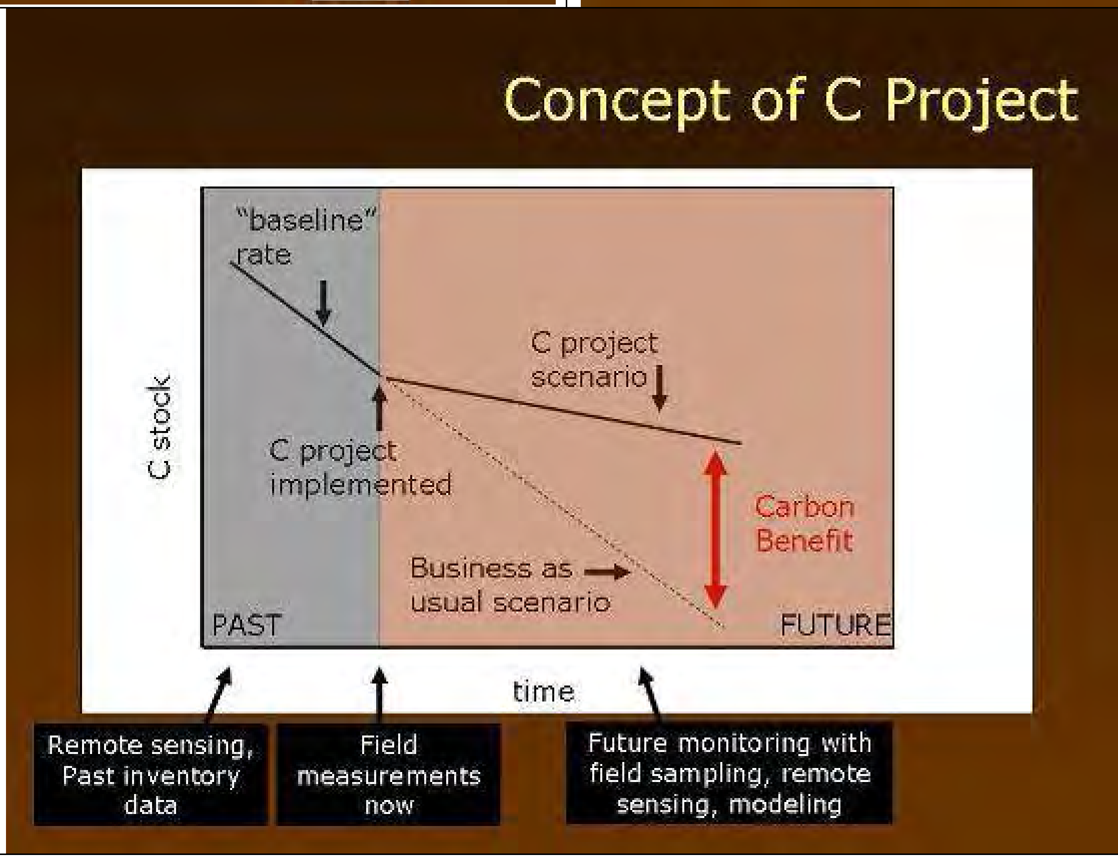


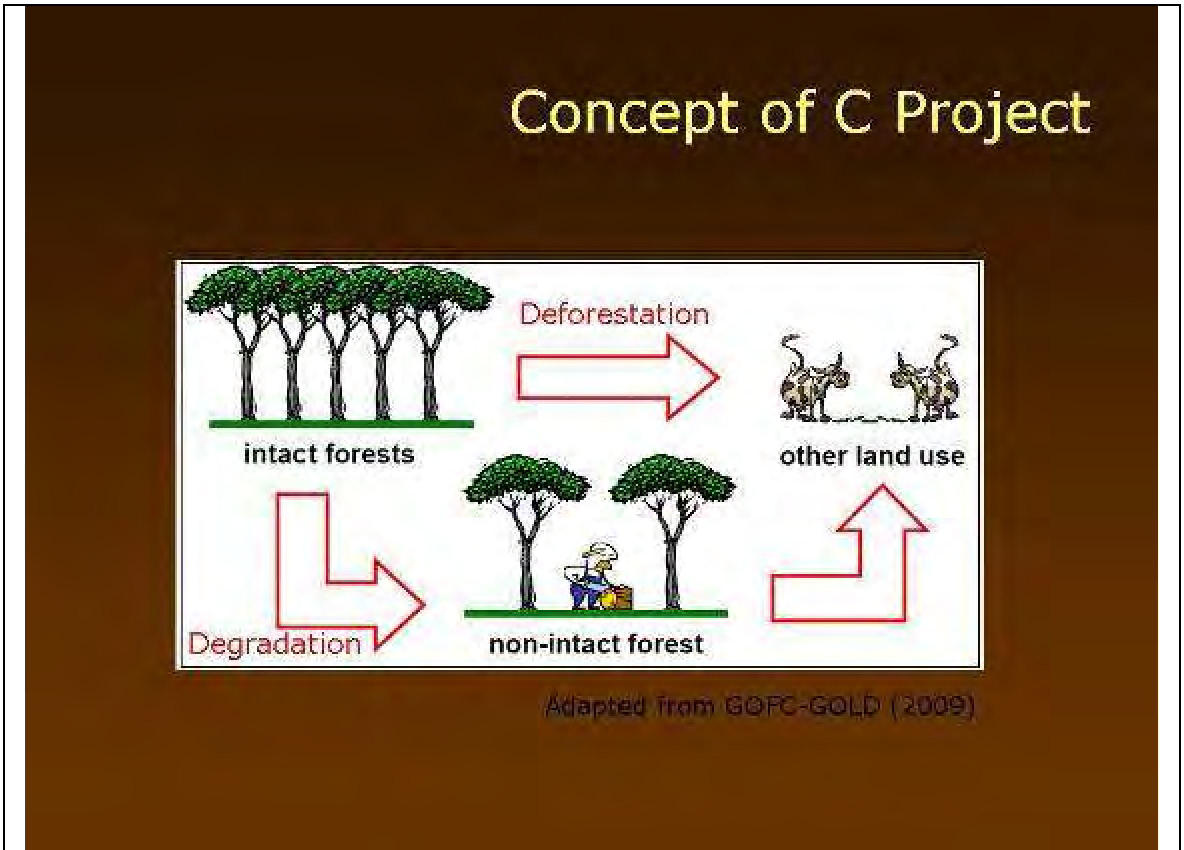


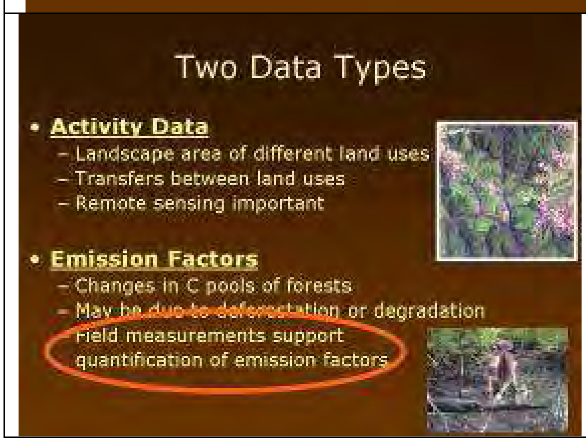


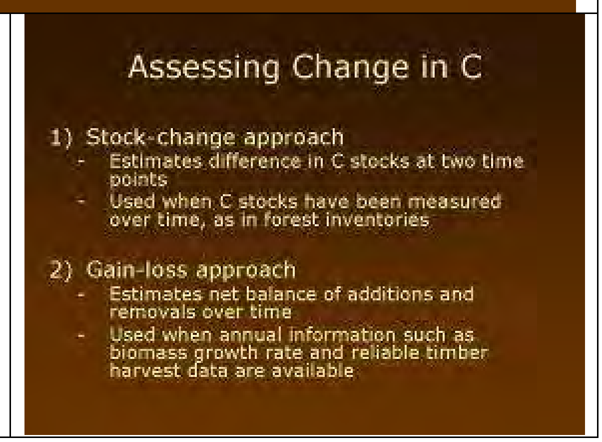

Essential Sources
• IPCC (2006) - Volumes 1 and 4
• GOFC-GOLD sourcebook (2009)
• LULUCF sourcebook
– (Pearson et al. 2005)
• USFS General Tech. Report NRS-18
– (Pearson et al. 2007)


Local Capacity and Inventories
• Forest inventory knowledge is already here
– Adapting existing methods not too difficult
– Use local knowledge—much of the best expertise on SRF and how to measure it is ultimately here with local professionals
– We are here to help provide guidance but flexibility/adaptation is needed
– Carbon example: Chunoti


Concept of C Project
"baseline" rate
C project scenario
C stock
C project implemented
Carbon Benefit
Business as usual scenario
PAST
FUTURE
time
Remote sensing, Past inventory data
Field measurements now
Future monitoring with field sampling, remote sensing, modeling


Concept of C Project
Deforestation
intact forests
other land use
Degradation
non-intact forest
Adapted from GOFC-GOLD (2009)


Two Data Types
• Activity Data
– Landscape area of different land uses
– Transfers between land uses
– Remote sensing important
• Emission Factors
– Changes in C pools of forests
– May be due to deforestation or degradation
– Field measurements support quantification of emission factors


Assessing Change in C
1) Stock-change approach
- Estimates difference in C stocks at two time points
- Used when C stocks have been measured over time, as in forest inventories
2) Gain-loss approach
- Estimates net balance of additions and removals over time
- Used when annual information such as biomass growth rate and reliable timber harvest data are available

Stock-Change Approach

Time 1

Time 2

$$\Delta C = C_{t2} - C_{t1}$$

Generalized Steps to Forest C Accounting

- Establish the baseline
- Quantify current C stocks
- Project future C stocks
- Monitor actual future C stocks

Tiers of C Assessment

- Tier 3 $$$
  - Detailed inventory of key C stocks
  - Repeated measurements of key stocks through time and/or modeling
- Tier 2 $$
  - Some country-specific data for key factors
- Tier 1 $
  - Default IPCC values
  - High error range (may be 50-90% or more)

Which tier for Sundarbans ?

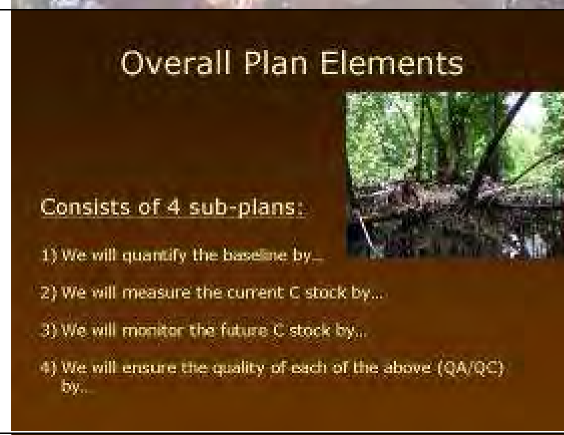
- Ultimately a local decision, many factors
- Some reasons for high tier:
  - A key terrestrial C stock for Bangladesh
  - Existing need for forest inventory data anyway
    - → very similar measurements
  - Existing inventory plot grid provides opportunity
  - Even a one-time effort to quantify C stocks will vastly improve estimates from Tier 1 to Tier 2

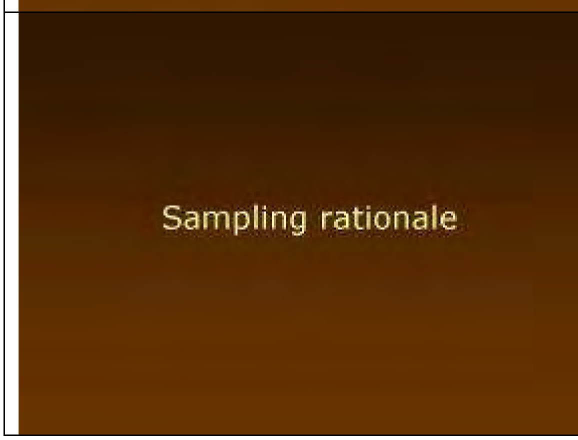
Project Design Considerations


Important Principles
Transparency
Methodologies and assumptions clearly explained, well justified, well documented, verifiable.
Consistency
The same definitions and methodologies should be used over time. Ensures that differences between years are real, not artifacts of analysis.
Comparability
Methods should be similar among countries. Thus, international standards should be followed (IPCC and sourcebooks).


Important Principles (contin.)
Completeness
Estimates should include all relevant C pools.
Accuracy
Estimates should be neither over or under the true value, and uncertainties quantified and reduced as much as possible.
Conservativeness
Minimize the risk of overestimating reductions in C emissions
Strongly recommend reading GOFC-GOLD pages 4-175 thru 4-178


Project Technical Components
Generate an overall plan
Design sampling scheme
Sample the forest
Analyze the data
Report C stocks
Monitoring plan for future
Quality Assurance / Quality Control (QA/QC)


Overall Plan Elements
Consists of 4 sub-plans:
1) We will quantify the baseline by…
2) We will measure the current C stock by…
3) We will monitor the future C stock by…
4) We will ensure the quality of each of the above (QA/QC) by…

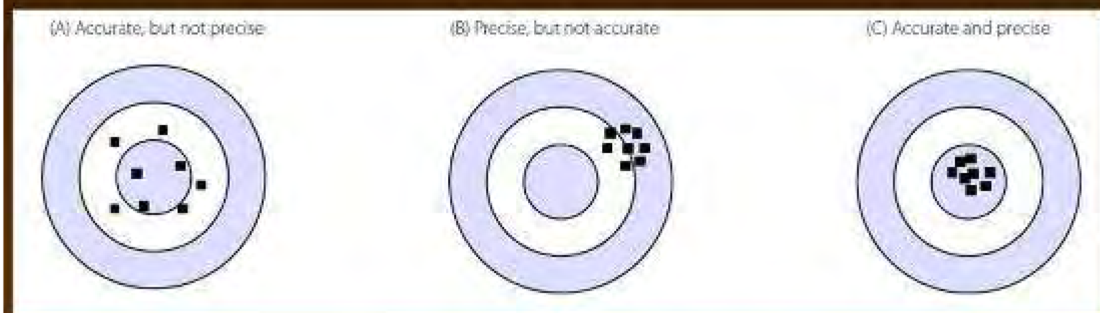

Sampling rationale


Sampling rationale
Ideally, we would measure every tree in area
In real life:
Must sample a subset of points to allow generalizations about whole area
Sample provides estimate of value for whole area
To evaluate how close the estimation is to reality, statistics are used

Sampling rationale

Sampling rationale

Accuracy and Precision

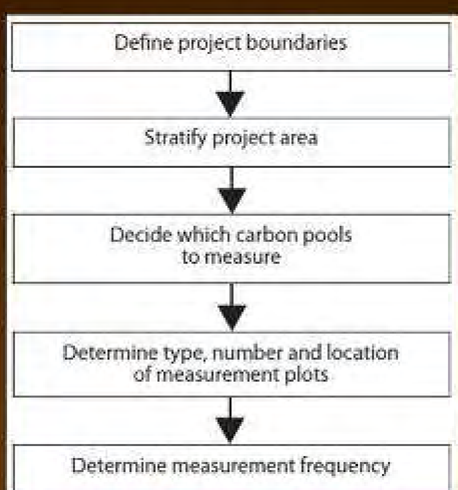


Accuracy is achieved by truly random sample

Precision is achieved by sampling a sufficient # of plots

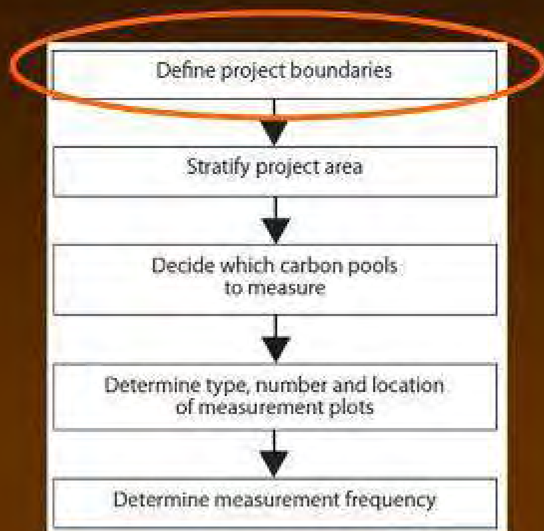
Both randomization and replication achieved

Designing the sampling scheme



From Pearson et al. (2005)

Defining the project boundary



From Pearson et al. (2005)

Spatial boundaries of project area need to be clearly defined and documented from the start

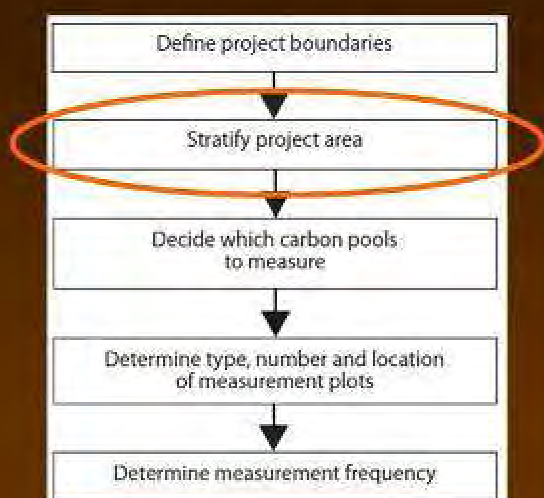
Use map and/or GPS coordinates

Could be tens to hundreds of thousands of hectares

In some cases it may be a stand-alone project area

In some cases an area may be part of larger national GHG inventory

To stratify or not to stratify



From Pearson et al. (2005)

Stratification divides an area into relatively homogenous units

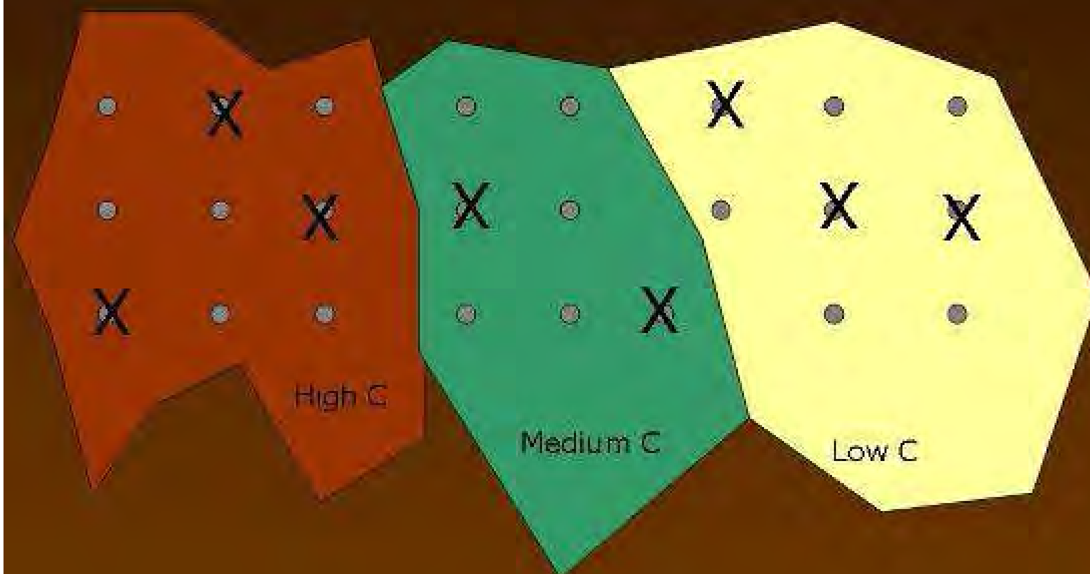
Lower variation within each unit means the same level of precision may be met with fewer plots (reduced costs)

Strata should be based on differentiating likely C stocks

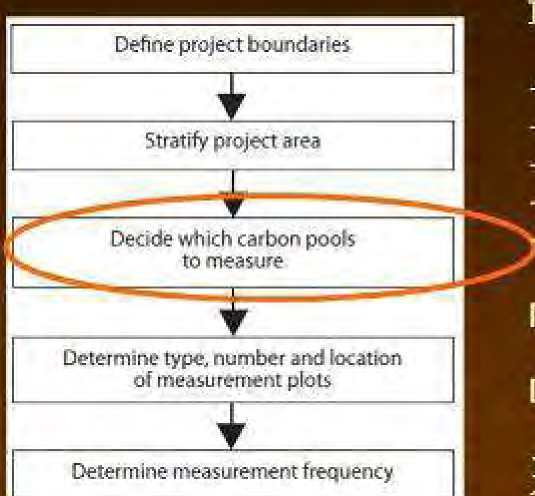
May be land use, vegetation type, soils, etc.

Use satellite imagery, aerial photos, or maps

Stratification



What C Pools to Measure ?



From Pearson et al. (2005)

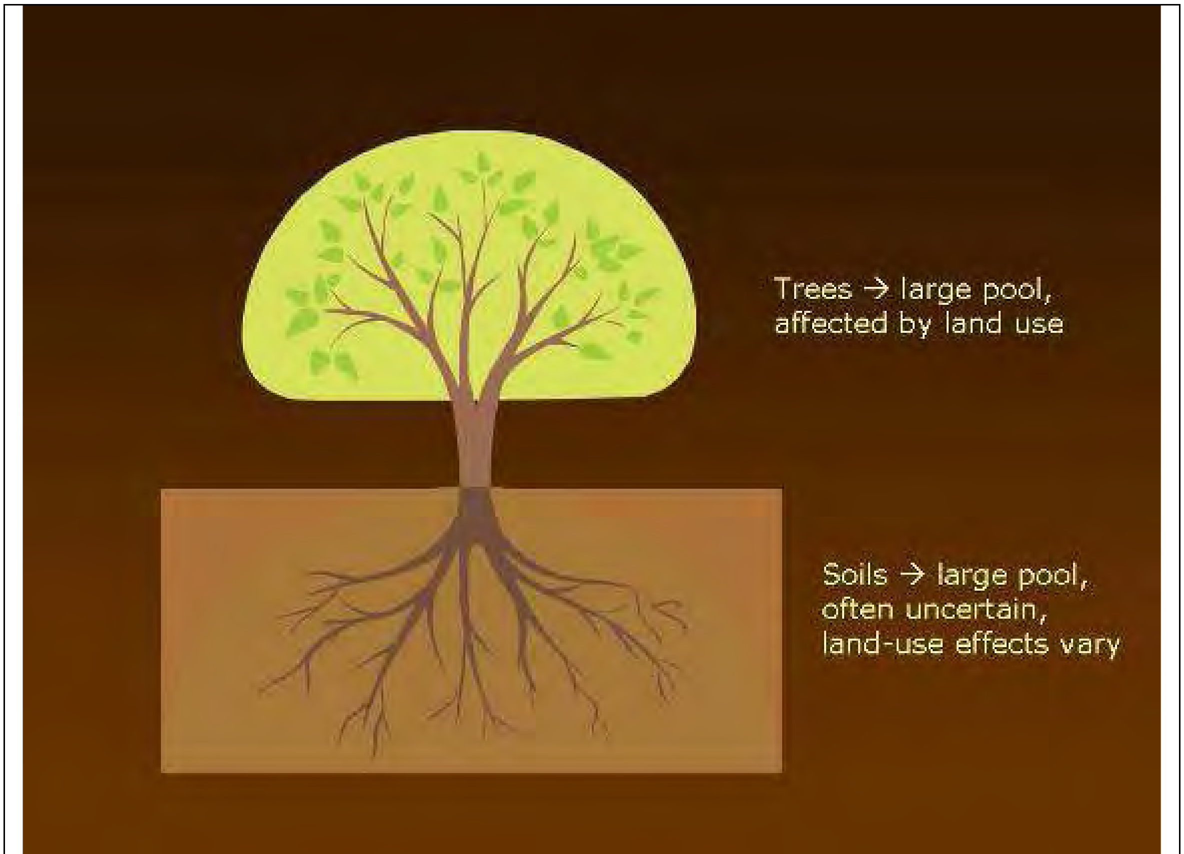
IPCC defines 5 forest C pools:

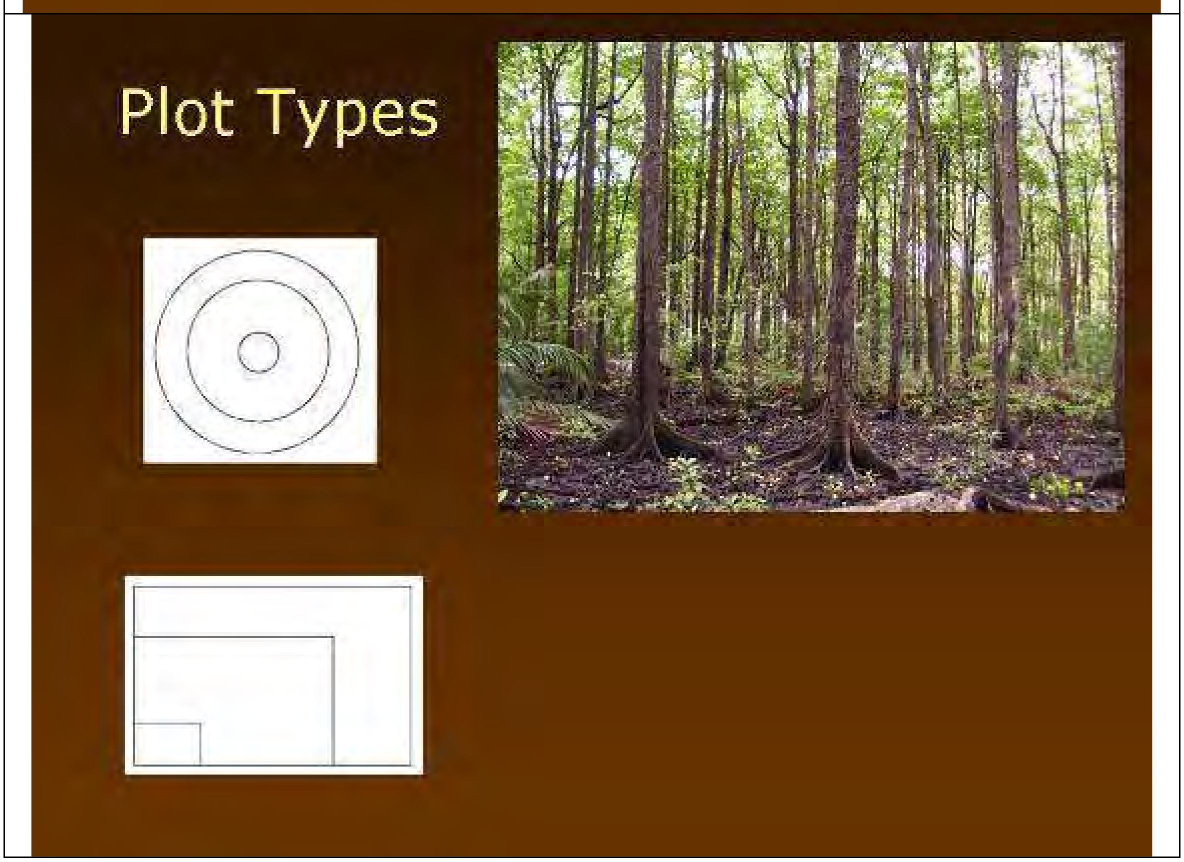
- trees (above- and belowground)
- non-tree vegetation
- dead wood
- forest floor (litter)
- soil

Not all must always be measured

Deciding factors:

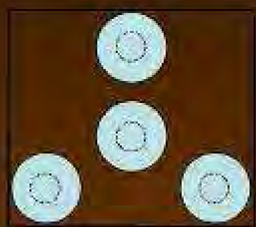
1) Is the pool large?
2) Is the pool likely to be affected by land use?
3) Is the pool uncertain?


Trees → large pool,
affected by land use
Soils → large pool,
often uncertain,
land-use effects vary

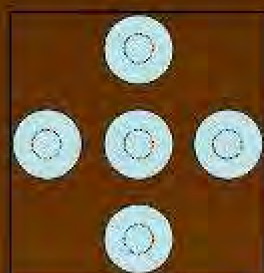

Plot Types

Plot Types

-clustering-



U.S. FIA / CVS



Indo-Pacific Forest C Study

How many plots ?

- Number of plots (sampling intensity) relates to precision and uncertainty
- In general: more = better
- In real life, must balance costs with needs
- There is no magic number for plot density (plots per area)
- Typical goal is to be within 10% of the true value at the 95% confidence level

How many plots ?

- We can use knowledge of variation in C stocks to estimate the needed number.
  → This knowledge comes from previous data or preliminary sample of 6-10 plots
- Simplest formula:

Minimum number of sample plots (n) = $\left(\frac{t*s}{E}\right)^2$

n = the number of sample plots,
t = the sample statistic from the t-distribution for the 95% confidence interval; t usually is set at 2 as sample size is unknown at this stage,
s = standard deviation expected or known from previous/initial data,
E = allowable error or the desired half-width of the confidence interval. Calculated by multiplying the mean carbon stock by the desired precision, i.e., mean * 0.1 (for 10 percent precision)

How many plots ?

- Example:
- Preliminary data show
  - C density ~ 300 Mg ha^{-1}
  - Standard deviation ~ 100 Mg ha^{-1}
  - Our objective is to be within 10%

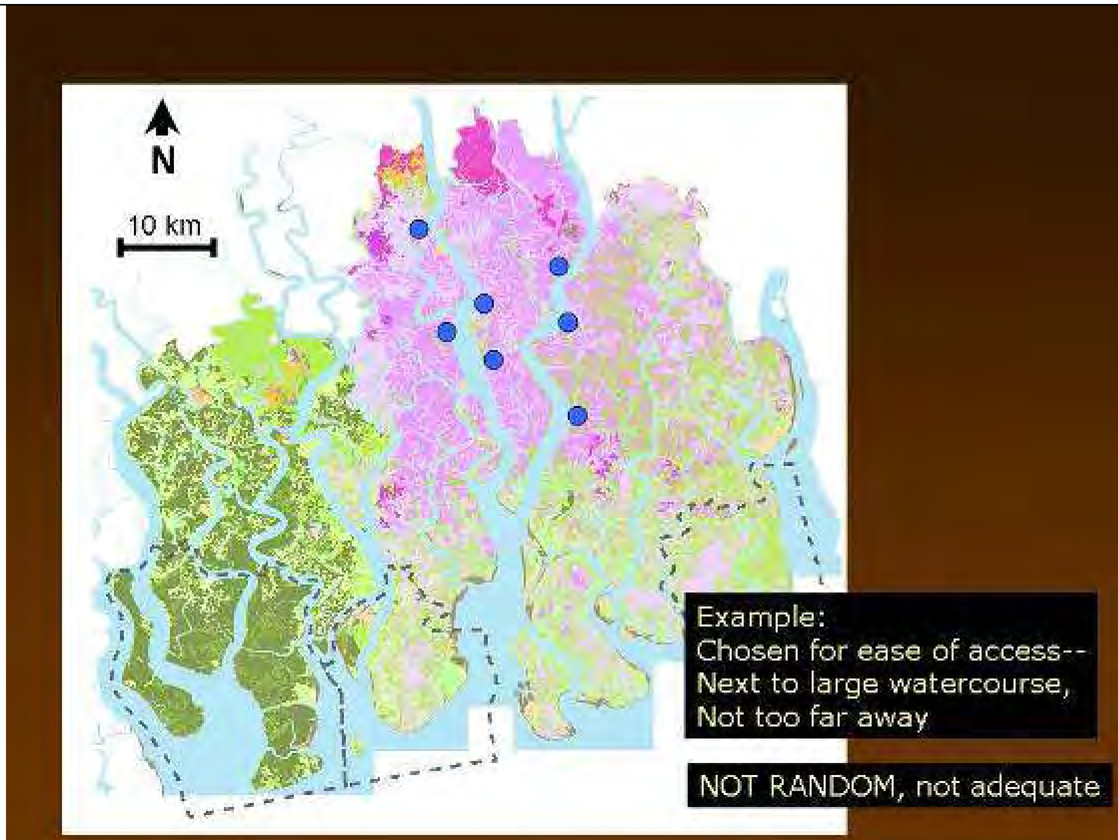
$$n = \left(\frac{2 * 100}{0.1 * 300}\right)^2$$

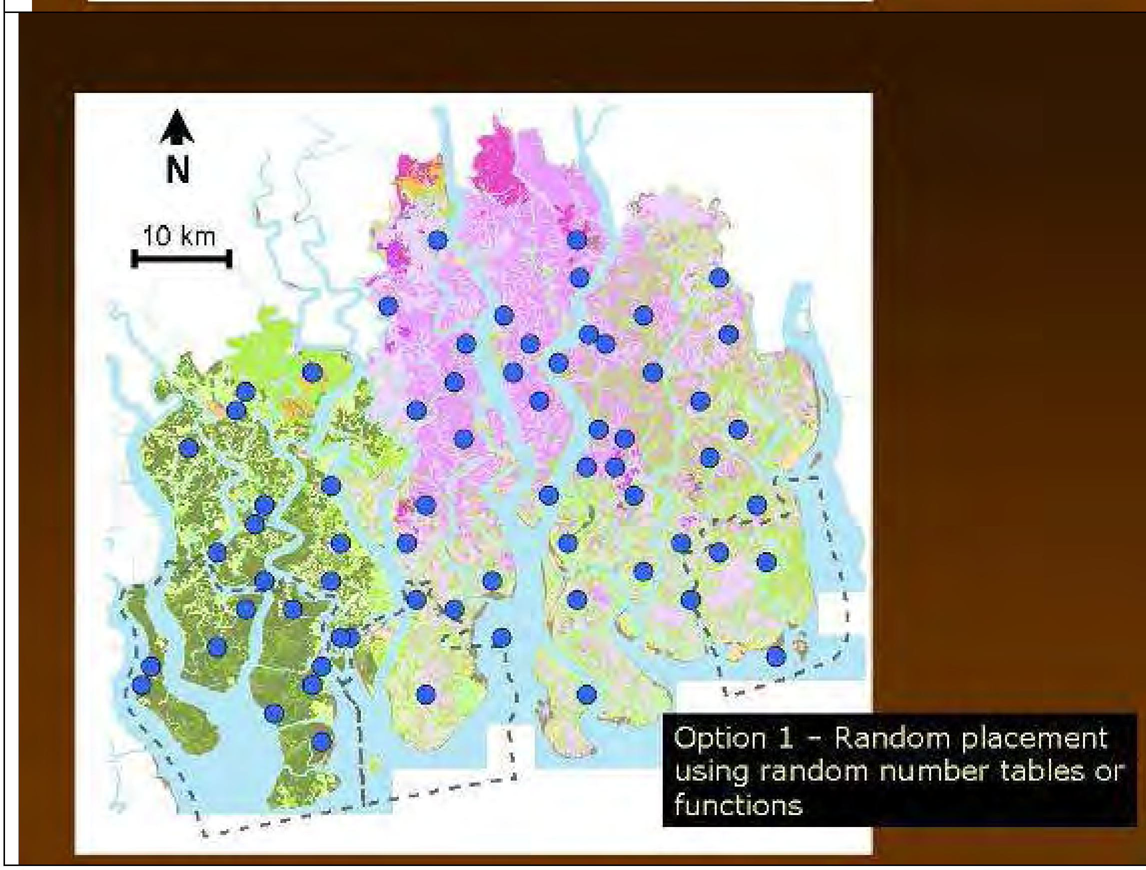
n = 44 plots

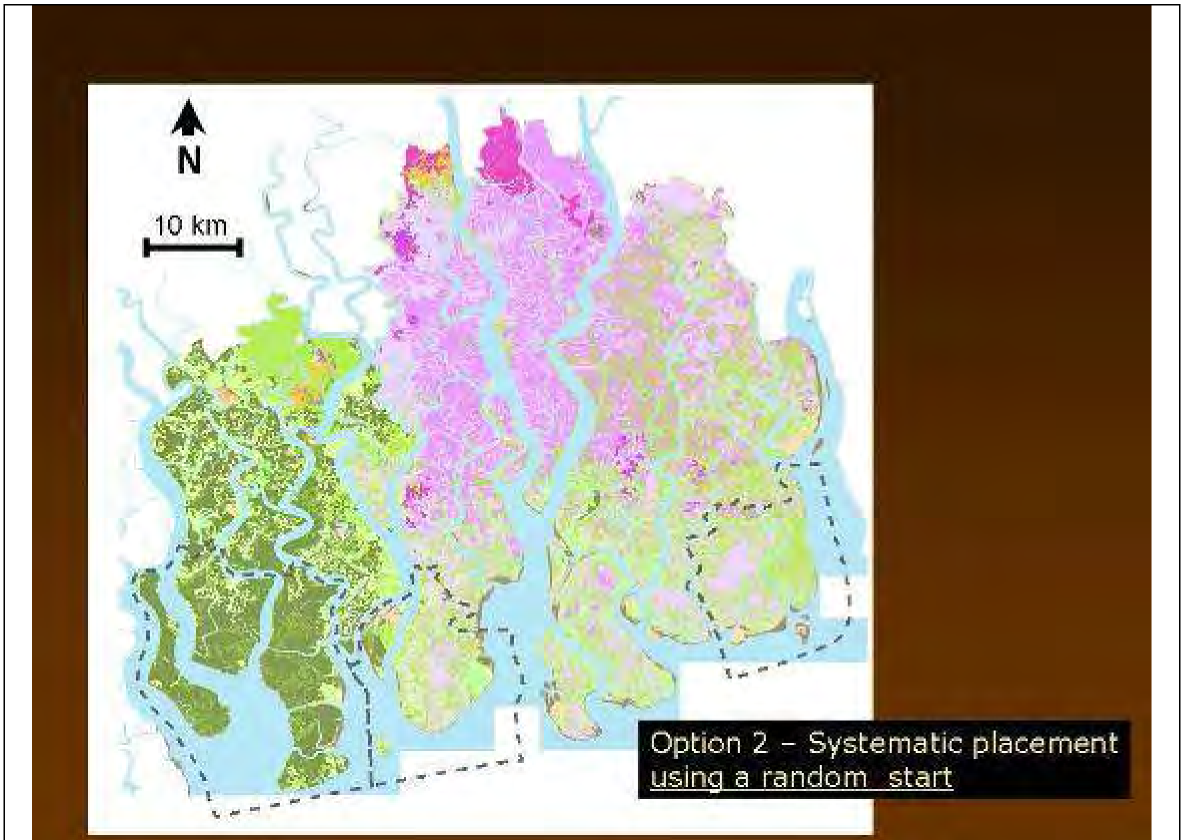
- Other factors:
  - Usually increased by ~10% to account for unforeseen circumstances
  - Geographic coverage
    - e.g., U.S. Forest Inventory program has used
      - 1 plot per 7.4 km^2 in accessible roaded areas
      - 1 plot per 30 km^2 in difficult-access roadless areas

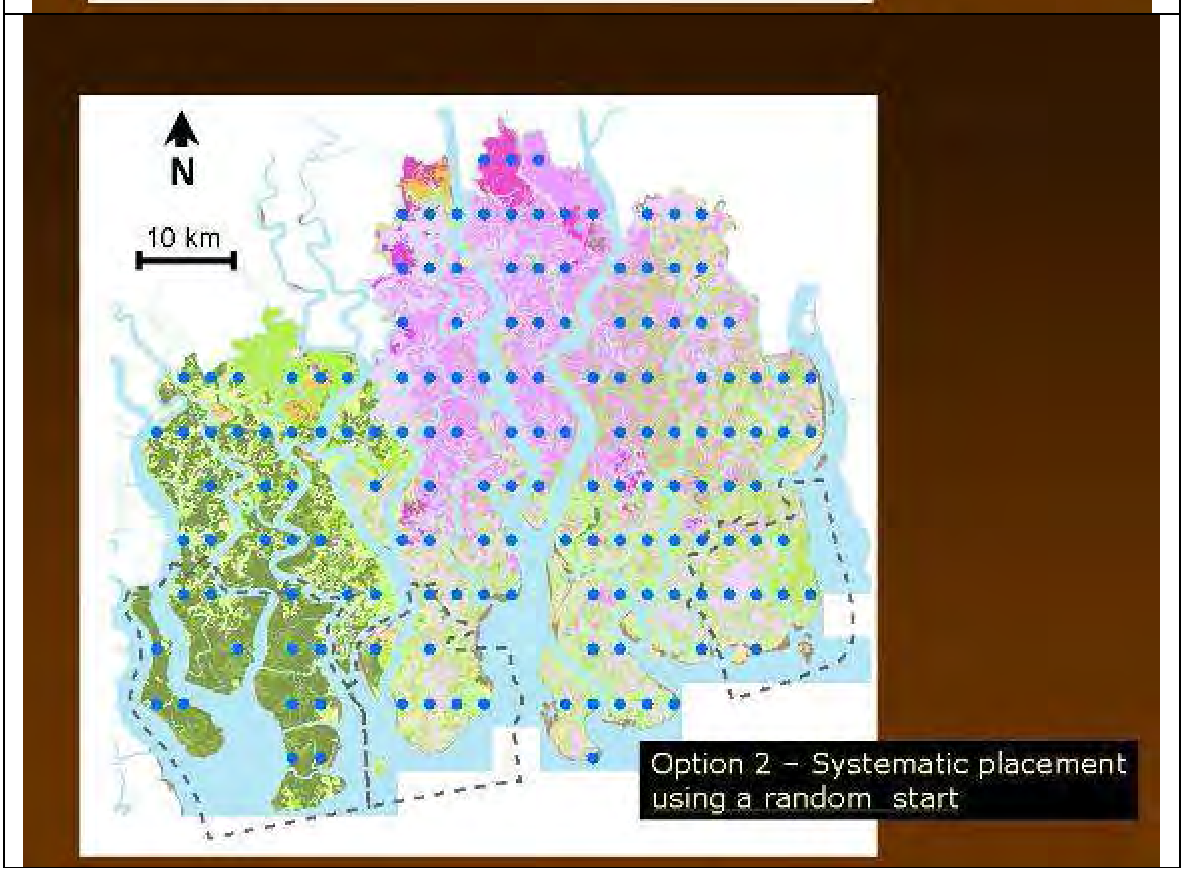
Where to place the plots ?

- Primary consideration: Avoid bias
- Achieved by random placement
  → All areas have equal chance of being selected


N
10 km
Example:
Chosen for ease of access--
Next to large watercourse,
Not too far away
NOT RANDOM, not adequate


N
10 km
Option 1 – Random placement
using random number tables or
functions


N
10 km
Option 2 – Systematic placement using a random start


N
10 km
Option 2 – Systematic placement using a random start

How often to monitor ?

- Cost-benefit analysis
- Expected magnitude and rate of change in C pools
- For forests, typical monitoring intervals are every 5 years
- Pools that change slowly, such as soils, may be measured less frequently → perhaps 10 or 20 years
- Check with given market; some require every 5 years for all pools

Concept of C Project

Historic rate of deforestation/ degradation → Current C stock

Current C stock → Future C stock with conservation

Current C stock → Future C stock With 'business as usual'

Difference is C benefit

Remote sensing, Past inventory data

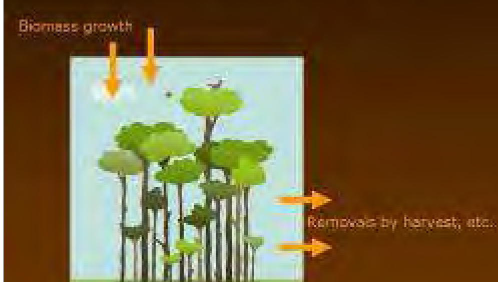
Field measurements now

Future monitoring with field sampling, remote sensing, modeling

Assessing Change in C

1) Stock-change approach
   - Estimates difference in C stocks at two time points
   - Used when C stocks have been measured over time, as in forest inventories

Gain-Loss Approach



PRESENTATION 9: POTENTIAL BARRIERS RELATED TO LAND-USE PROJECTS IN BANGLADESH. DR. RAM SHARMA, DCOP, IPAC PROJECT

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Certificate Training Course on Carbon Financing Project Preparation

Potential Barriers related to land-use projects in Bangladesh

1 Nov. 2009

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Special characteristics of land-use projects

- Additionality – Parties being paid for the actions that they would have taken anyway
- Leakage – Diverted emissions beyond project boundaries
- Permanence – Release of stored carbon (intentionally or accidently) before or after project ends
- Governance – How project related decisions are made and implemented locally

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Barrier Analysis

- Barrier analysis is necessary to determine whether the proposed project activity faces barriers that:

  - prevent the implementation of this type of proposed project activity, and

  - do not prevent the implementation of at least one of the alternatives

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Barrier Analysis for Chunoti Carbon Project

- Listing of Barriers as per the PDD
- Step 1 : How the identified barrier prevents the project implementation activity?
- Step 2 : How the identified barrier does not prevent the project implementation activity

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Investment Barrier 1 : Debt funding is not available

- Step 1 : Banks have not funded forestry projects
- Step 2 : Forests will continue to be in degraded conditions

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Investment Barrier 2 : No access to international capital markets

- Step 1 : Forestry project, being long gestation activity, face difficulties in attracting capital markets
- Step 2 : Degraded forests will continue

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Investment Barrier 3 : Lack of access of credit

- Step 1 : FD has not taken credits for long gestation forestry projects
- Step 2 : Baseline scenario will continue

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Institutional Barrier 1 : Risks related to changes in in government policies or laws

- Step 1 : Forest land security with FD
- Step 2 : Baseline situation will continue as forestry laws do not permit private ownership rights on govt. forest land

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Institutional Barrier 2 : Lack of enforcement of forest or land-use related legislation

- Step 1 : Involvement of CMOs will help enforce relevant legislations
- Step 2 : Baseline situation will continue

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Technological Barrier 1 : Lack of access to planting material

- Central and temporary nurseries will provide seedlings of indigenous tree species
- Degraded forest land will not be planted

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Technological Barrier 2 : Lack of infrastructure for implementation of the technology

- Step 1 : Reforestation will require facilities for developing nurseries and plantations, and that is not possible in the absence of adequate funds
- Step 2 : Baseline situation will continue

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Local Tradition Barrier 1 : Traditional knowledge or lack thereof laws and customs, market conditions, practices

- Step 1 : Local people are gainfully involved through CMOs
- Step 2 : Baseline scenario will continue as majority of the local stakeholders are poor

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Local Tradition Barrier 2 : Traditional equipment and technology

- Step 1 : Reforestation technologies are understood locally through communication activities
- Step 2 : Baseline scenario will continue as adequate resources are neither available with FD nor with CMOs

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Prevailing Practice Barrier 1 : The project activity is the first of its kind

- Step 1 : Reforestation of degraded forest land has in past been taken up by FD but not as forest carbon activity
- Step 2 : Baseline scenario will continue

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Ecological Barrier 1 : Degraded soil

- Step 1 : Ecological conditions prevailing in Chunoti are largely favorable for reforestation
- Step 2 : Baseline scenario will continue

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Ecological Barrier 2 : Catastrophic events (landslides, fire, etc.)

- Step 1 : Landslides are not very common and forest fires will be controlled by involving CMOs
- Step 2 : Baseline situation will continue

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Ecological Barrier 3 : Unfavorable conditions such as drought

- Step 1 : Drought is not common in the area
- Step 2 : Baseline scenario will continue

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Social Barrier 1 : Demographic pressure

- Step 1 : CMOs will help check biotic pressure
- Step 2 : Forest land may come under encroachment in the absence of reforestation activity

Social Barrier 2 : Social conflicts locally

- Step 1 : CMOs will help resolve local conflicts
- Step 2 : Baseline scenario will continue

Social Barrier 3 : Lack of skills locally

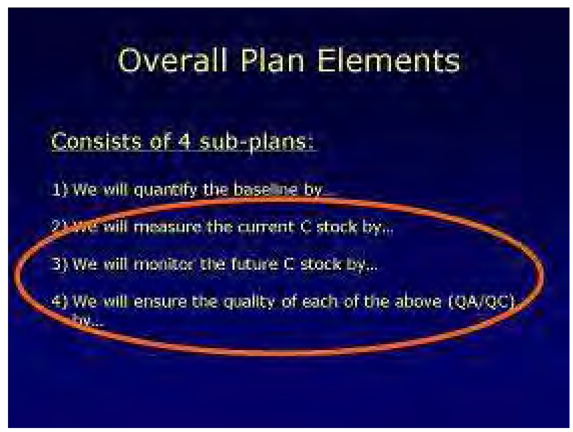
- Step 1 : Reforestation skills are available locally
- Step 2 : Reforestation skills will remain unutilized

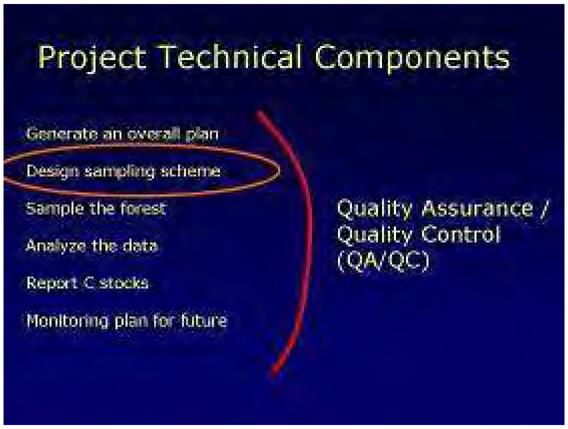
Market Barriers 1 : Transport and storage

- Step 1 : As no harvesting is allowed in the Sanctuary this barrier is not applicable

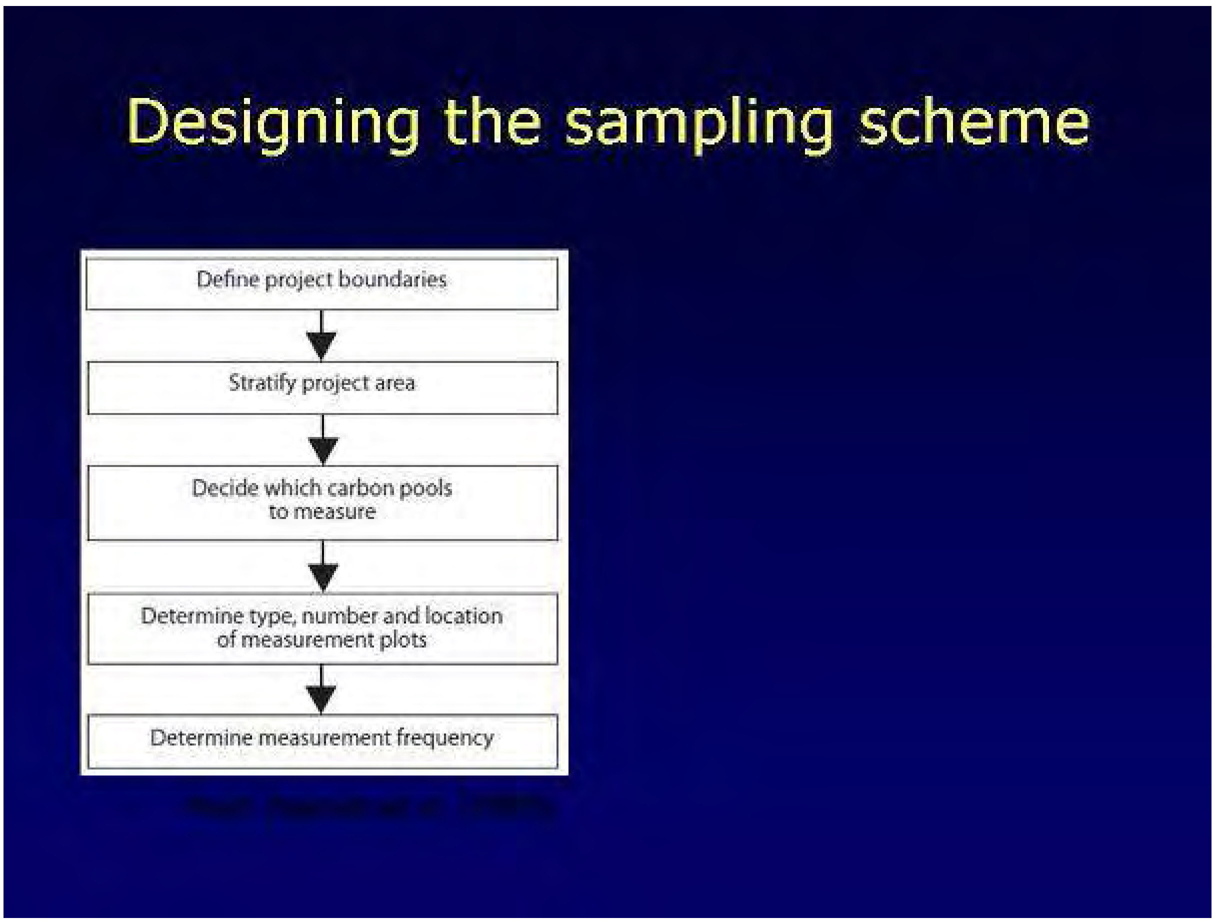
- THANKS

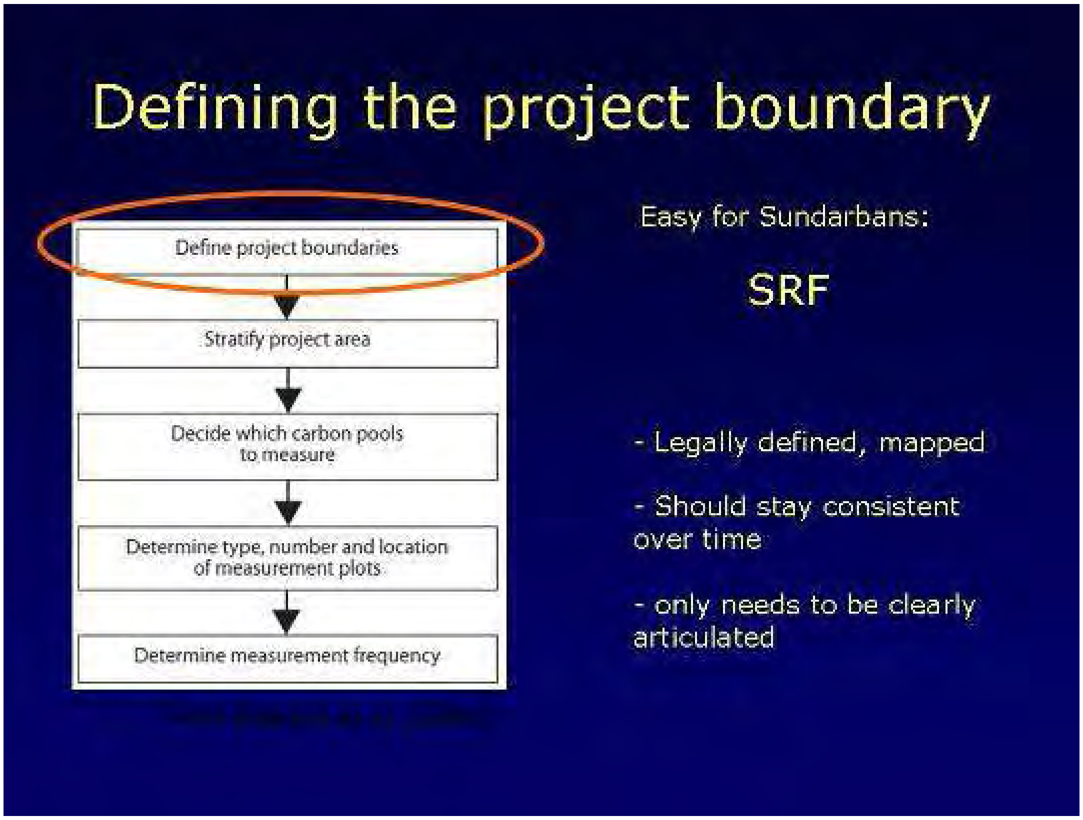
PRESENTATION 10: DESIGNOF A SUNDARBANS CARBON ASSESSMENT. D.C. DONATO, M.A. STIDHAM, J.B. KAUFFMAN, USFS

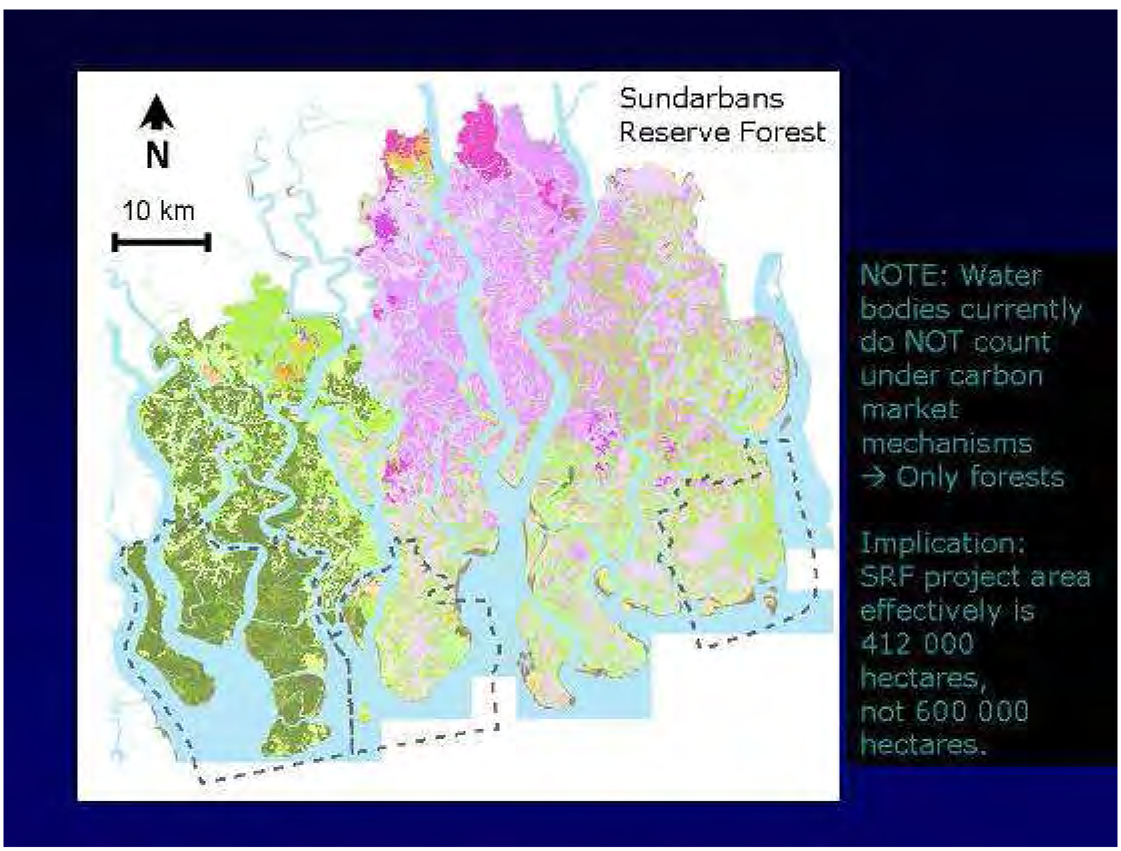


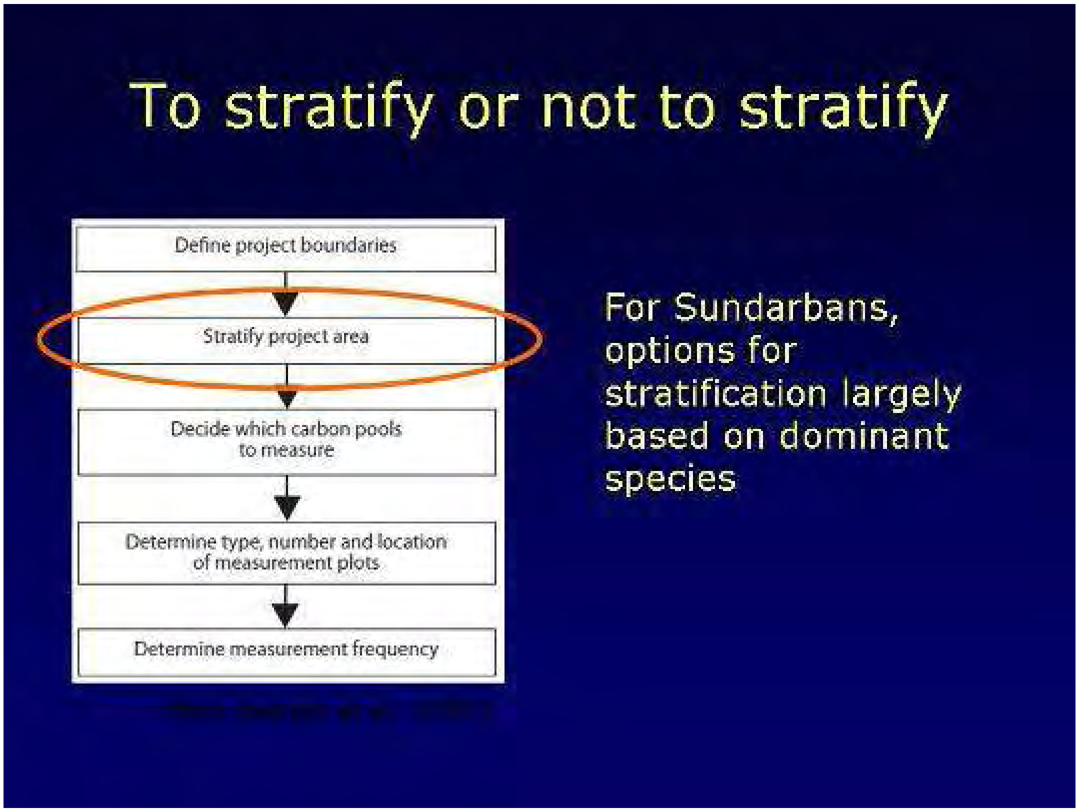

Project Technical Components
Generate an overall plan
Design sampling scheme
Sample the forest
Analyze the data
Report C stocks
Monitoring plan for future
Quality Assurance / Quality Control (QA/QC)

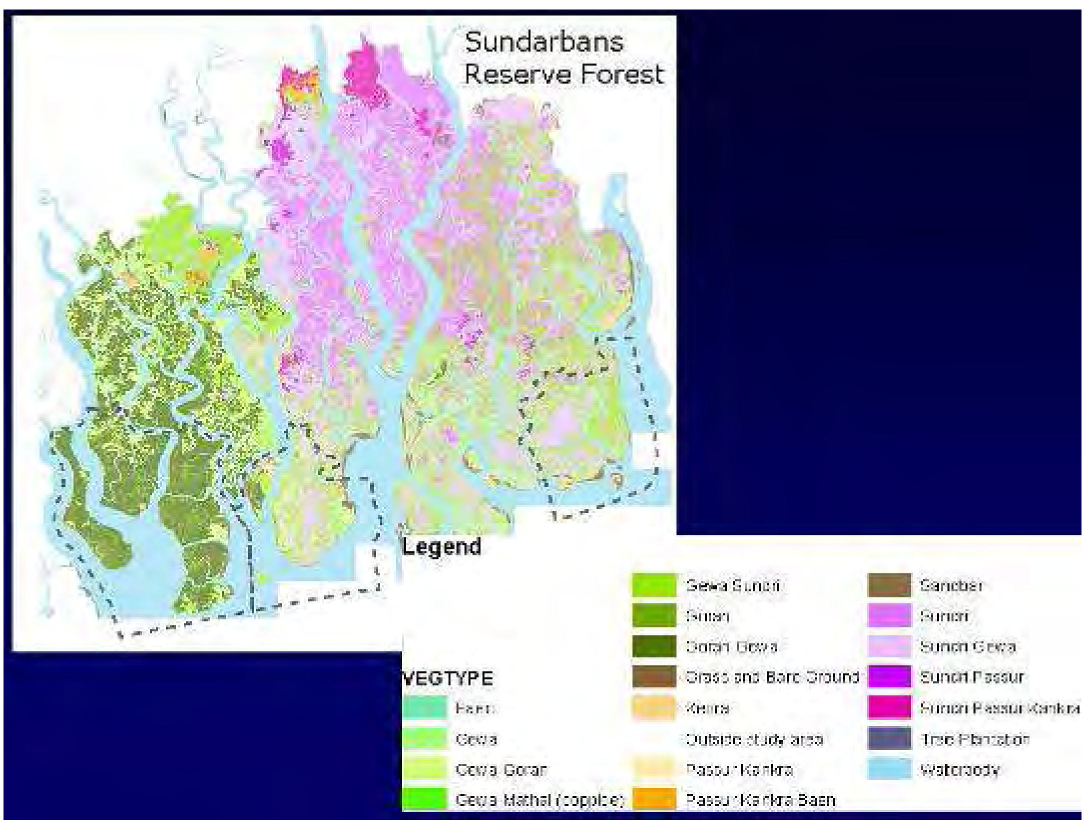

Important Principles
Transparency
Consistency
Comparability
Completeness
Accuracy

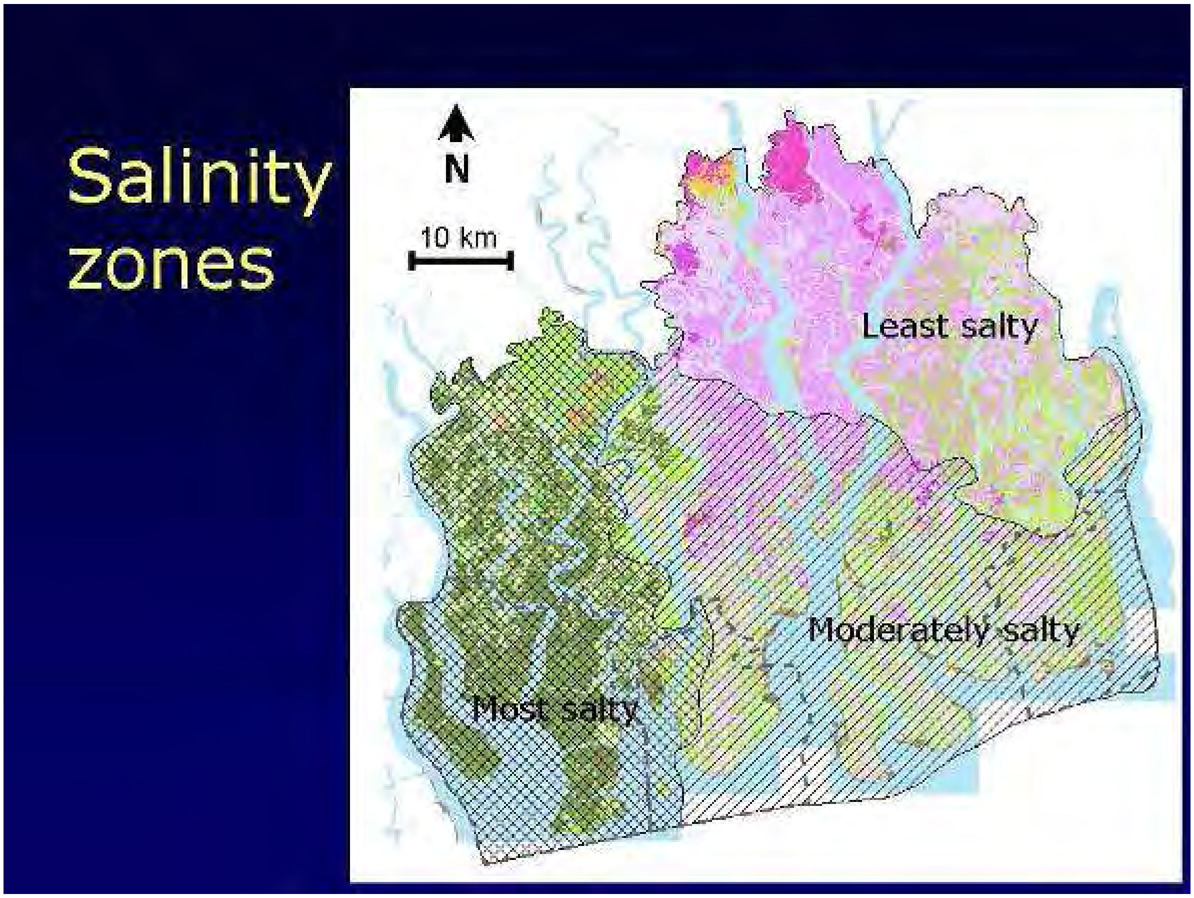

Designing the sampling scheme
Define project boundaries
Stratify project area
Decide which carbon pools to measure
Determine type, number and location of measurement plots
Determine measurement frequency


Defining the project boundary
Define project boundaries
Stratify project area
Decide which carbon pools to measure
Determine type, number and location of measurement plots
Determine measurement frequency
Easy for Sundarbans:
SRF
- Legally defined, mapped
- Should stay consistent over time
- only needs to be clearly articulated


N
10 km
Sundarbans Reserve Forest
NOTE: Water bodies currently do NOT count under carbon market mechanisms
→ Only forests
Implication: SRF project area effectively is 412 000 hectares, not 600 000 hectares.

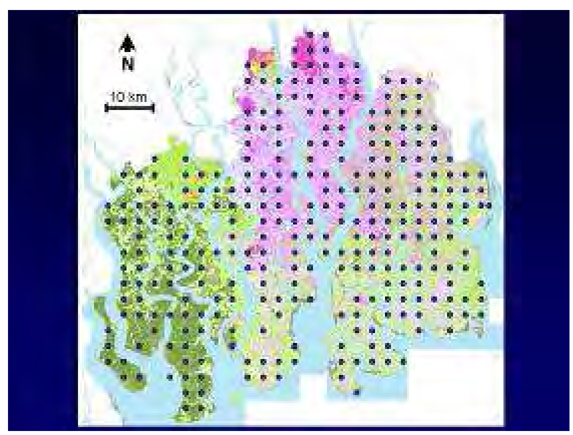

To stratify or not to stratify
Define project boundaries
Stratify project area
Decide which carbon pools to measure
Determine type, number and location of measurement plots
Determine measurement frequency
For Sundarbans, options for stratification largely based on dominant species


Sundarbans Reserve Forest
Legend
VEGTYPE
Gewa
Gewa Goran
Gewa Mathal (coppice)
Gewa Sundri
Goran Gewa
Grass and Bare Ground
Outside study area
Passur Kankra
Passur Kankra Baen
Sundri
Sundri Gewa
Sundri Passur
Tree Plantation
Waterbody

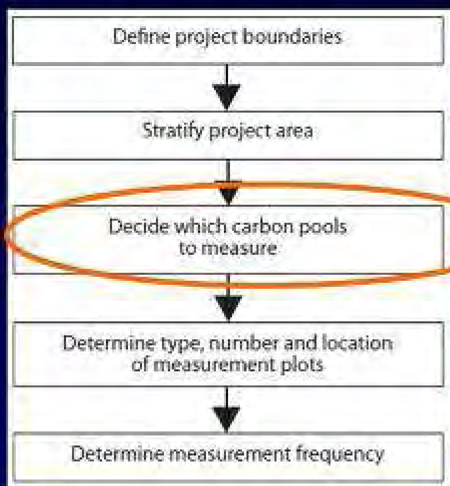


Stratification (contin.)

- Several reasons not to stratify SRF:
  1) Existing inventory plot grid is a powerful tool (consistency principle)
  2) Systematic grid was randomly placed (accuracy principle) and is the most credible and sellable layout
  3) Sundarbans is dynamic region, directional changes occurring
     - salinity, hydrology, sedimentation, top-dying disease, sea level incursion
     → a stratification today may not make sense tomorrow



What C Pools to Measure ?



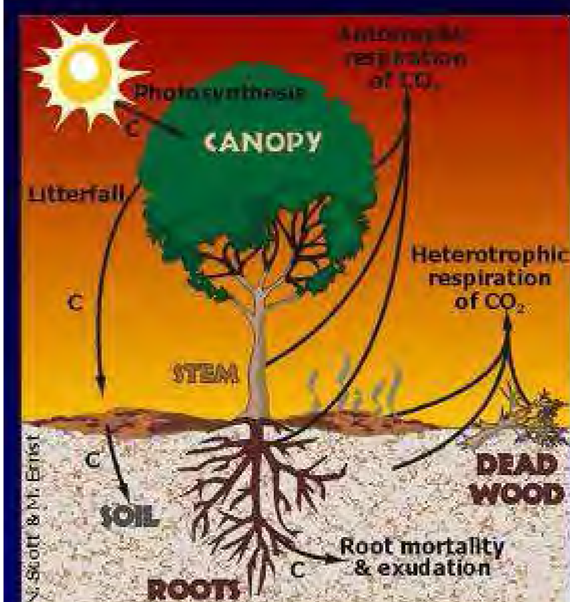
IPCC defined forest C pools:

- trees (above- and belowground)
- non-tree vegetation
- dead wood
- forest floor (litter)
- soil

Not all must always be measured

Deciding factors:

1) Is the pool large?
2) Is the pool likely to be affected by land use?
3) Is the pool uncertain?



✓ Trees → large pool, affected by land use

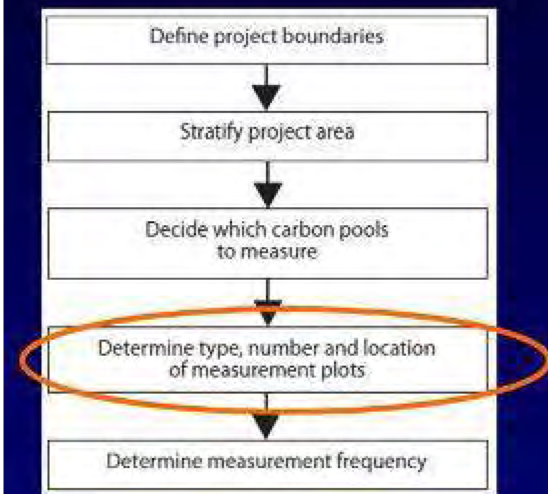
✓ Non-tree vegetation → may increase in importance with forest degradation, not hard to measure

✓ Dead wood → important in mature forests, changes with land use

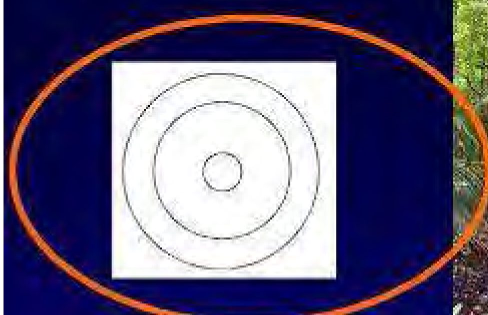
✗ Forest floor → sometimes important, usually not in mangroves, time-consuming to measure

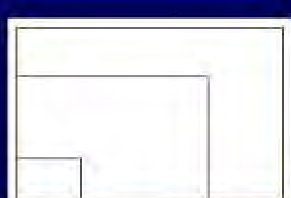
✓ Soils → large pool, often uncertain, land-use effects vary

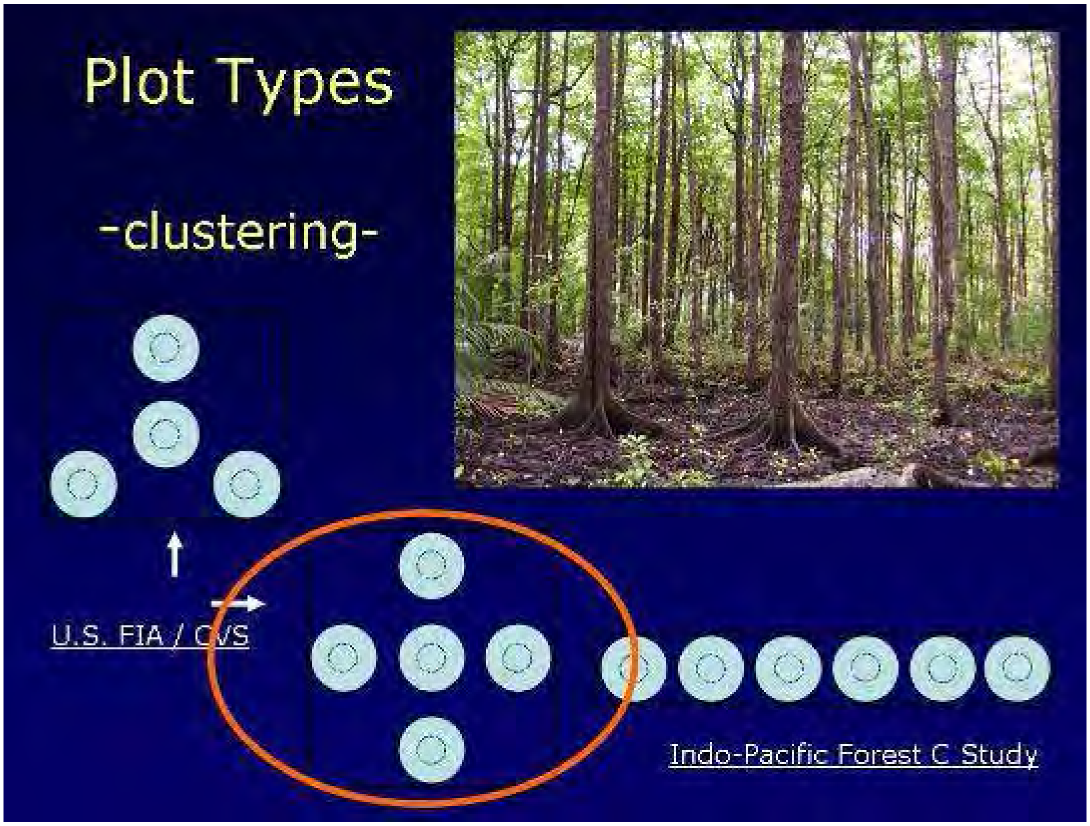
Type, number, & location of plots

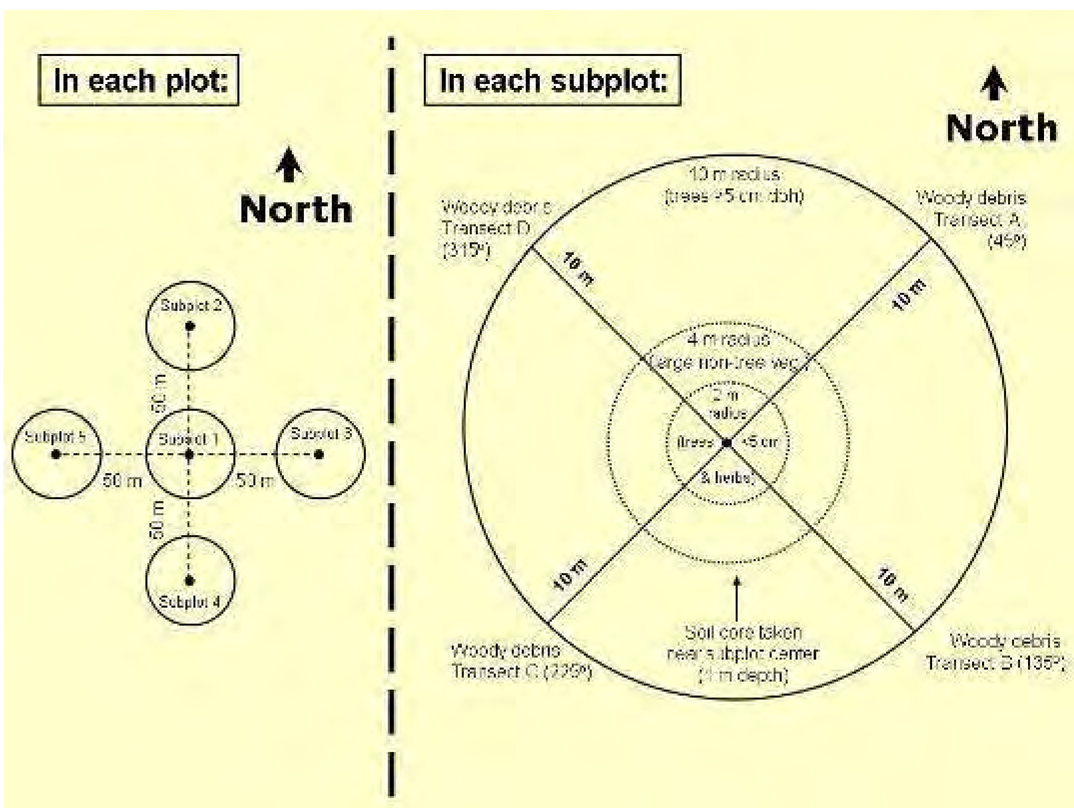


Plot Types






Plot Types
-clustering-
U.S. FIA / CVS
Indo-Pacific Forest C Study


In each plot:
North
Subplot 2
Subplot 5
Subplot 1
Subplot 3
Subplot 4
50 m
50 m
50 m
50 m
In each subplot:
North
10 m radius
(trees >5 cm dbh)
Woody debris
Transect A
(45°)
Woody debris
Transect D
(315°)
10 m
10 m
4 m radius
(large non-tree veg.)
2 m
radius
(trees <5 cm
& herbs)
10 m
10 m
Soil core taken
near subplot center
(1 m depth)
Woody debris
Transect C (225°)
Woody debris
Transect B (135°)

How many plots ?

- We can use knowledge of variation in C stocks to estimate the needed number.
  - → This knowledge comes from previous data or preliminary sample of 6-10 plots
- Goal: Within 10% of the mean, with 95% confidence
- Simplest formula:

$$\text{Minimum number of sample plots } (n) = \left(\frac{t^{*}s}{E}\right)^{2}$$

n = the number of sample plots,
t = the sample statistic from the t-distribution for the 95% confidence interval; t usually is set at 2 as sample size is unknown at this stage,
s = standard deviation expected or known from previous/initial data,
E = allowable error or the desired half-width of the confidence interval. Calculated by multiplying the mean carbon stock by the desired precision, i.e., mean * 0.1 (for 10 percent precision)

How many plots ?

- Preliminary estimate:
  - C density ~ 300 Mg ha^{-1}
  - Standard deviation = 60% of mean ~ 180 Mg ha^{-1}
  - Our objective is to be within 10%
  - Can adjust this based on actual analysis of previous inventory data

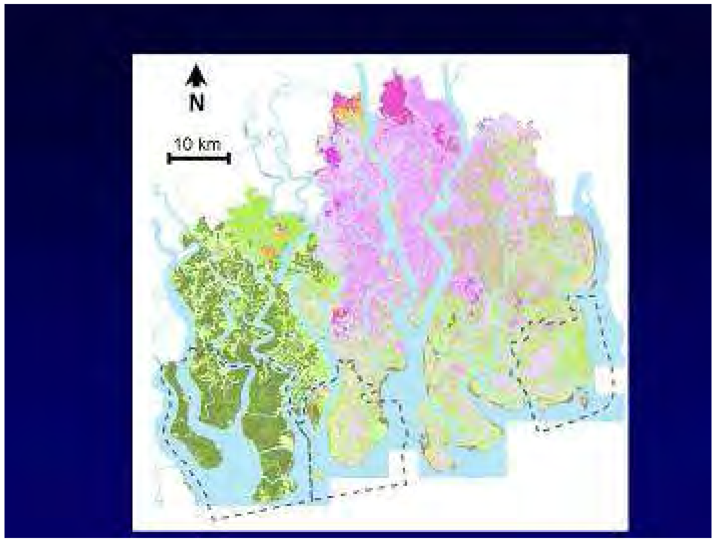
$$n = \left(\frac{2 * 180}{0.1 * 300}\right)^{2}$$

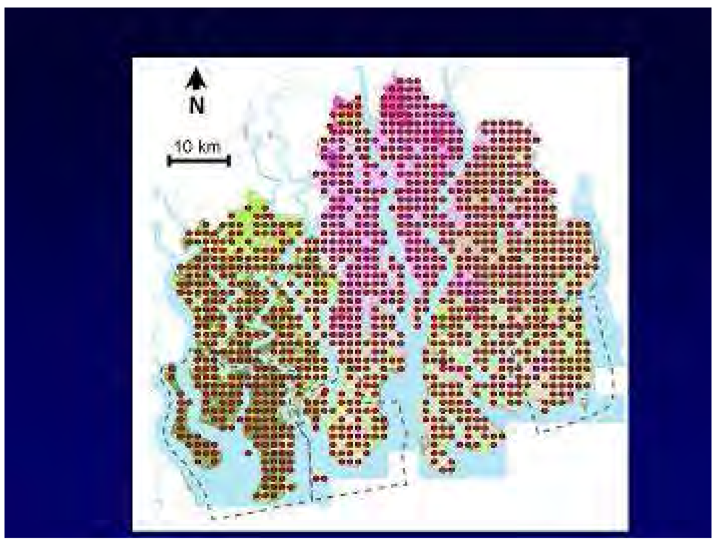
n = 144 plots

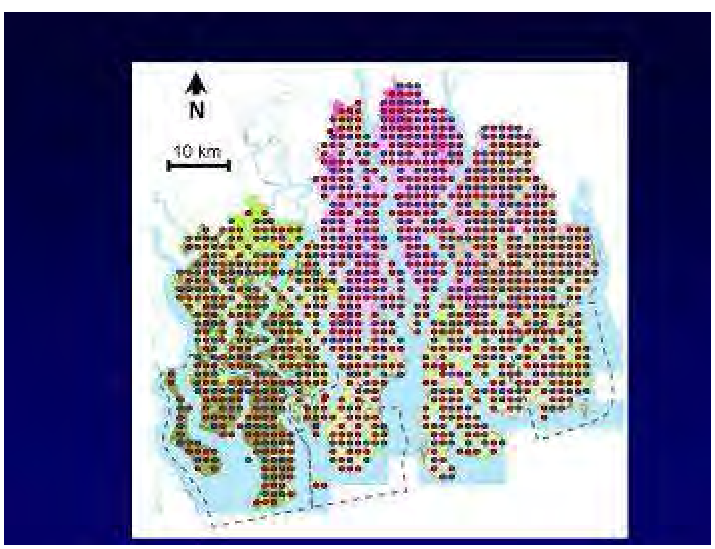
- Other factors:
  - Increase by 10%: 144 + 14 = 158
  - Geographic coverage
    - recall U.S. Forest Inventory (FIA) program has used 1 plot per 30 km^2 in difficult-access roadless areas
      - → would equate to ~ 135 plots for SRF

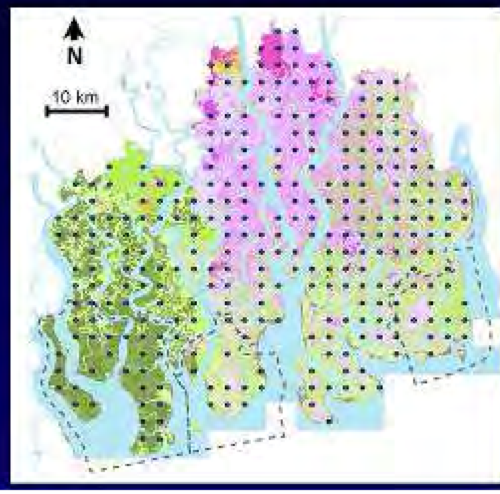
Where to place the plots ?

- Primary consideration: <u>Avoid bias</u>
- Achieved by random placement
  - → All areas have equal chance of being selected


N
10 km


N
10 km


N
10 km



Some Options

	1 small pilot study area	1 large pilot study area	SRF combined inventory, low density	SRF combined inventory, med. density	SRF combined inventory, high density (soil in only ½ of plots)
# plots	12	30	105	155	285
# plots in which soil is sampled	12	30	105	155	155
# soil samples to be analyzed	24	60	210	310	310
time needed	1 month	1 - 2 months	4 months	4 months	4 - 5 months
# crews	1	1 – 2	2	3	4
# crew members (not incl. guards)	6	6 – 12	12	18	24

How often to monitor ?

- Best to plan for every 5 years
- Pools that change slowly, such as soils, may be measured less frequently → perhaps every 10 years
- Check with given market; some require every 5 years for all pools

PRESENTATION 11: DEVELOPING A PROJECT CONCEPT REPORT (PCR) AND PROJECT DESIGNS DOCUMENT (PDD). DR. RAM SHARMA, DCOP, IPAC PROJECT

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Certificate Training Course on Carbon Financing Project Preparation

Developing a Project Concept Report (PCR) and Project Designs Document (PDD)

1 Nov. 2009

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Project Concept Report (PCR)

- PCR is a brief note, which conveys the idea about the type of the project, its location, the expected schedule, the financial analysis, risk analysis, technical summary and the expected environmental benefits
- PCR provides the basic information which helps in decision making process for the award of "Endorsement" or the "Host Country Approval" by Designated National Authority (DNA)

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Project Concept Report (PCR)

- A PCR will consist of approximately 5 pages providing indicative information on :
  - the type and size of the project
  - its location
  -the anticipated GHG reductions
  - the suggested crediting life time
  - the suggested carbon price (USD/tC)
  - the expected project financing
  - the projects' environmental and socio-economic effects/benefits

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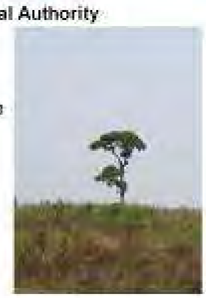
Bangladesh Designated National Authority

- CDM Committee chaired by the Secretary, MOEF
- CDM Board chaired by the Principal Secretary to Prime Minister



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Project Designs Document (PDD)

- PDD is a document, which is prepared by project promotors (e.g. FD/DOF), providing the detailed information of the project
- PDD format and guidelines are provided by UNFCCC and most of the investors follow them

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Project Designs Document (PDD) - Contents

- A. General description of the proposed project activity
  - Title of the proposed project activity
  - Description of the project activity
  - Project participants
  -Technical description of the project activity

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Project Designs Document (PDD) - Contents

- B. Duration of the project activity/crediting period
  -Starting date of the proposed project activity and of the crediting period
  - Expected operational lifetime of the proposed project activity
  - Choice of crediting period and related information

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Project Designs Document (PDD) - Contents

- C. Application of approved baseline and monitoring methodology
  - Assessment of eligibility of land
  - Title and reference to the approved baseline and monitoring, applied to the proposed project activity
  - Assessment of the applicability of the selected approved methodology to the proposed project activity and justification of the choice of the methodology
  - Description of the strata identified using the ex-ante stratification
  - Identification of baseline scenario
  - Assessment of demonstration of additionality
  - Estimation of ex ante baseline net GHG removals by sinks
  - Date of completion of the baseline study and the name of person(s)/entity(ies) determining the baseline

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Project Designs Document (PDD) - Contents

- D. Estimation of ex ante net anthropogenic GHG removals by sinks
  - Estimate of the ex ante net GHG removals by sinks
  - Estimate of the ex ante leakage

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Project Designs Document (PDD) - Contents

- E. Monitoring Plan
  - Monitoring of the project implementation
    - Monitoring of the project boundary
    - Monitoring of forest establishment
    - Monitoring of forest management
  - Sampling design and stratification
  - Monitoring of the baseline net GHG removals by sinks
  - Monitoring of the actual net GHG removals by sinks
  - Quality control and quality assurance procedures undertaken for data monitored
  - Operational and management structures that the project operator will implement for monitoring

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CCB Standards : 15 Required Criteria & 8 Optional Criteria

- Community Section (CM)
  -CM1. Net Positive Community Impacts
  -CM2. Offsite Community Impacts
  -CM3. Community Impact Monitoring
  -CM4. Capacity Building
  -CM4. Management capacity (1 Point)
  -CM5. Best Practices in Community Involvement (1 Point)

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CCB Standards : 15 Required Criteria & 8 Optional Criteria

- Biodiversity Section (B)
  -B1. Net Positive Biodiversity Impacts
  -B2. Offsite Biodiversity Impacts
  -B3. Biodiversity Impact Monitoring
  -B4. Native Species Use (1 Point)
  -B5. Water and soil resource enhancement (1 Point)

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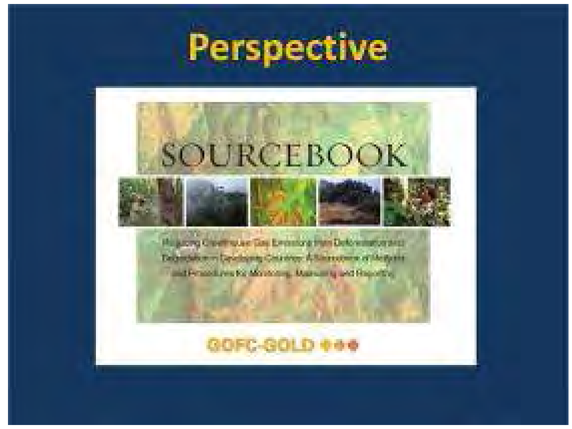
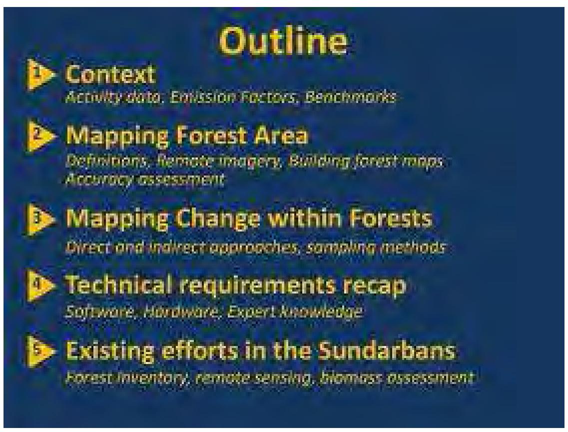
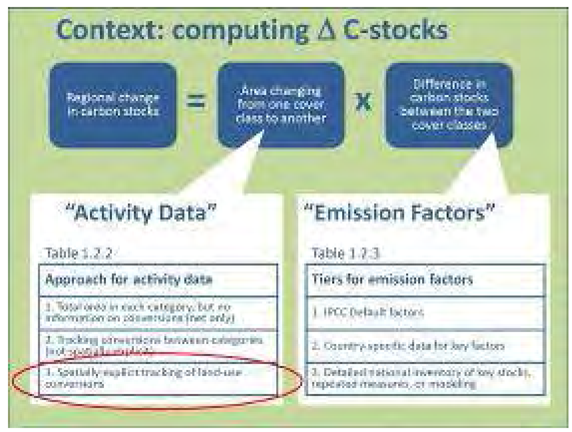
CCB Standards Validation Levels

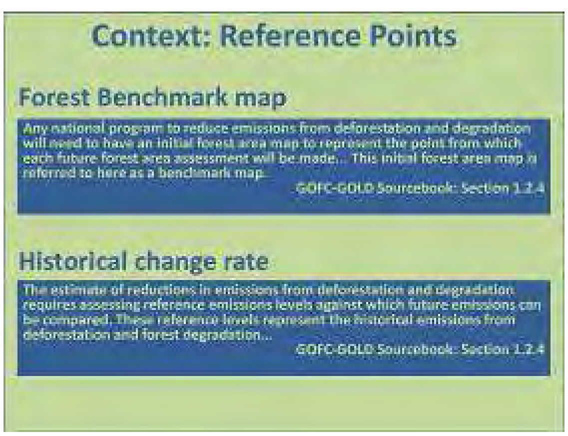
- Approved – all requirements met
- Silver – all requirements met + one point minimum from at least three different Sections
- Gold – all requirements met + six points minimum, at least one point from four different Sections

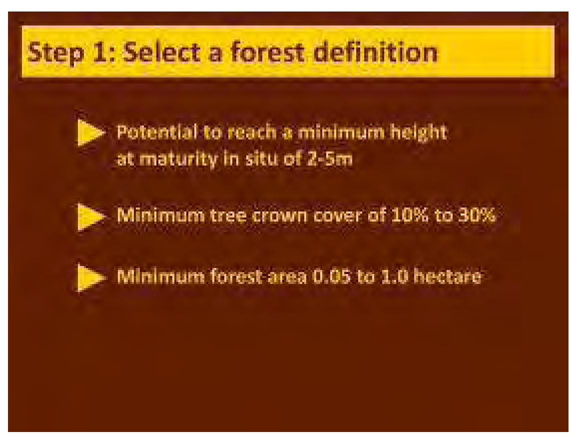
PRESENTATION 12: MAPPING VEGETATION FROM REMOTE IMAGERY.DR. JOHN CAMPBELL, USFS











Step 2: Define the forest area

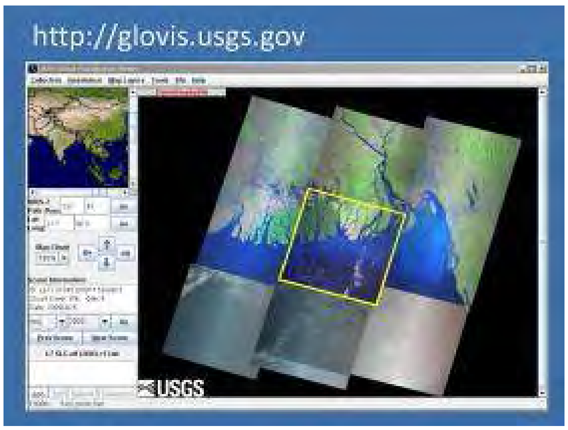
It is not necessary to map an entire country if forest land is limited to certain regions. However when eliminating regions from analysis, the following considerations must be made

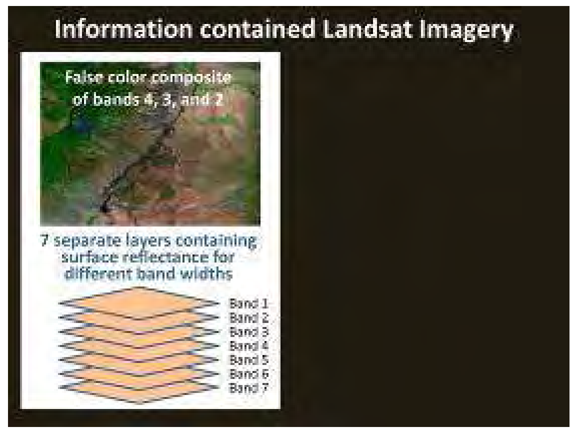
- No forests should be excluded
- Extent should remain constant between assessment periods
- *Therefore*, should include areas wherein aforestation may occur

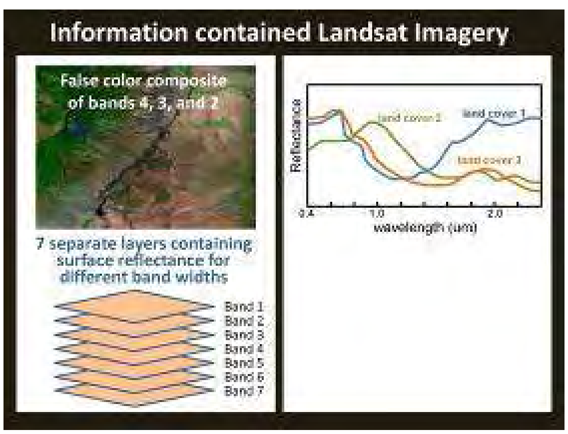
Step 3: select remote imagery

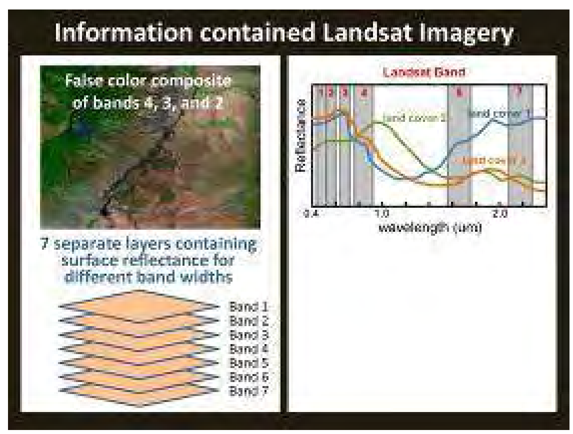
Several to choose from; but I will limit my discussion to the utility Landsat imagery for these reasons:

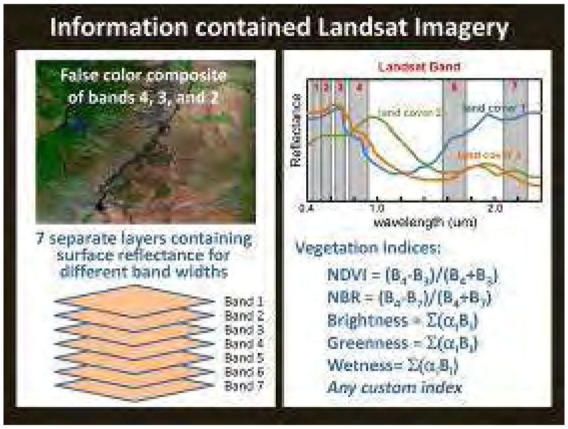
- 30 m spatial resolution
- Spectral resolution captures the principle components of vegetation reflectance
- Great spatial coverage
- Excellent historical archive (to 1972)
- Available on the web at no charge

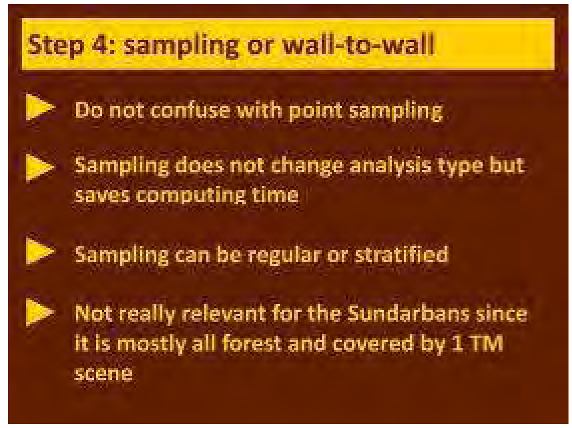


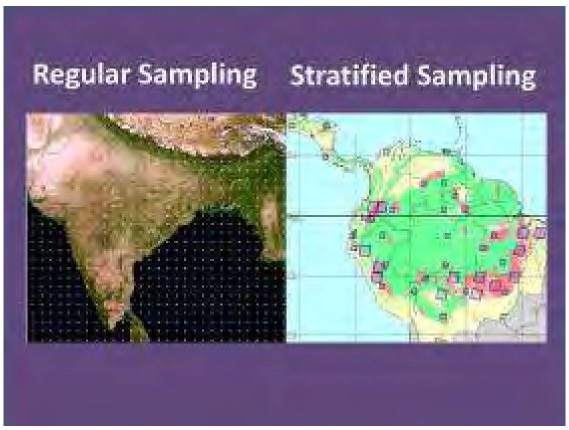


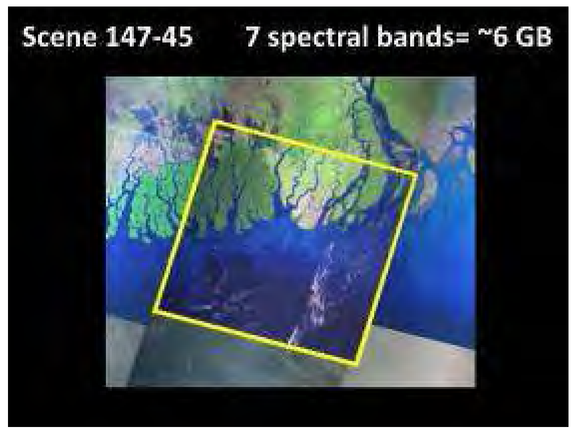


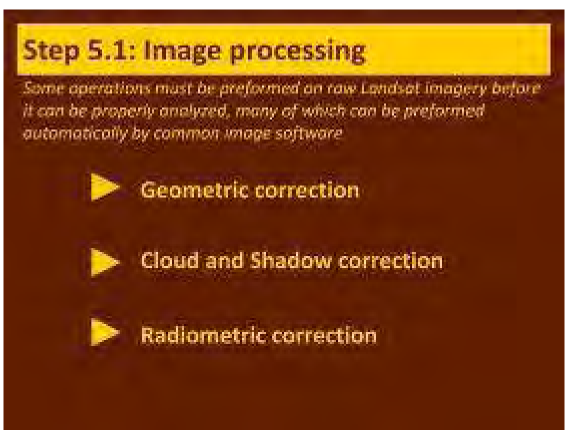



Information contained Landsat Imagery
False color composite of bands 4, 3, and 2
7 separate layers containing surface reflectance for different band widths
Band 1
Band 2
Band 3
Band 4
Band 5
Band 6
Band 7
Landsat Band
Reflectance
wavelength (um)
Vegetation Indices:
NDVI = $(B_4-B_3)/(B_4+B_3)$
NBR = $(B_4-B_7)/(B_4+B_7)$
Brightness = $\Sigma(\alpha_i B_i)$
Greenness = $\Sigma(\alpha_i B_i)$
Wetness= $\Sigma(\alpha_i B_i)$
Any custom index


Step 4: sampling or wall-to-wall
Do not confuse with point sampling
Sampling does not change analysis type but saves computing time
Sampling can be regular or stratified
Not really relevant for the Sundarbans since it is mostly all forest and covered by 1 TM scene


Regular Sampling
Stratified Sampling


Scene 147-45
7 spectral bands= ~6 GB

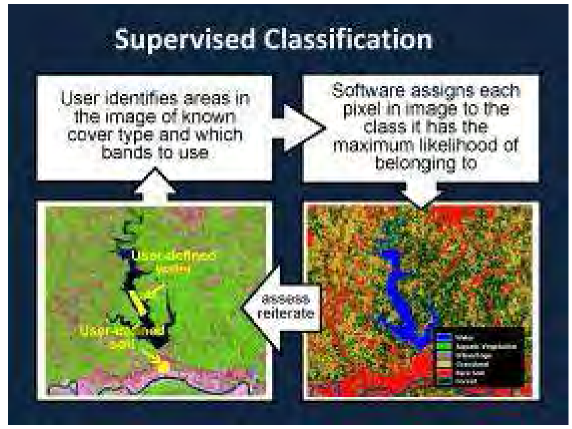

Step 5.1: Image processing
Some operations must be preformed on raw Landsat imagery before it can be properly analyzed, many of which can be preformed automatically by common image software
Geometric correction
Cloud and Shadow correction
Radiometric correction

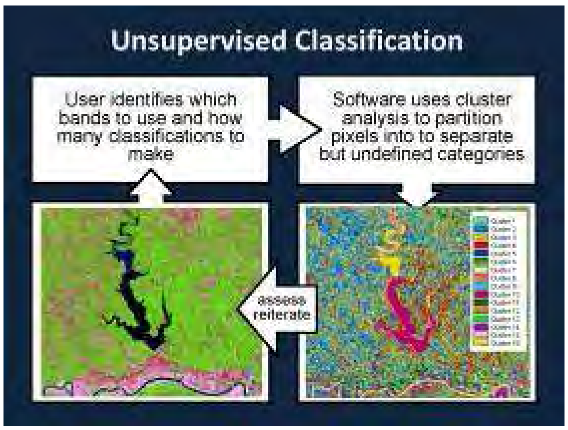

Step 5.2: Cover classification
Here is where the real analysis occurs
Landsat Image
Cover map
50
100
Reflectance
Forest 1
Shrubland
Urban
Beach
Cropland
Water

Step 5.2: Cover classification

Here is where the real analysis occurs

- Visual delineation of imagery into cover classes is acceptable
- Automated classification is more objective and really quite tractable
  - Unsupervised classification
  - Supervised classification





Step 5.2: Cover classification

Here is where the real analysis occurs

- Visual delineation of imagery into cover classes is acceptable
- Automated classification is more objective and really quite tractable
  - Unsupervised classification
  - Supervised classification

Classified Vegetation Map

Bangladesh Sundarbans 1995

Created by M. Runkel and others in 1996 by interpretation of aerial photos

Step 6: Accuracy assessment

- Truth could come from ground data or from higher-resolution imagery such as air photos
- Distinguish between errors of omission and commission
- Overall accuracies of 80-98% are commonly achievable when distinguishing forest from non forest

Google Earth

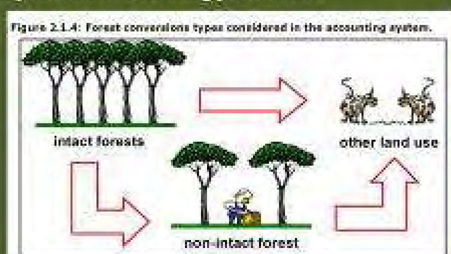
Typical Error matrix

As truthed on ground (columns); As classified on map (rows)

	Water	Forest Class A	Forest Class B	Cropland	Total	commission accuracy
Water	50	0	0	0	50	100%
Forest Class A	0	40	6	4	50	80%
Forest Class B	0	4	28	18	50	56%
Cropland	0	3	0	47	50	94%
Total	50	47	34	69		
omission accuracy	100%	85%	82%	68%		

Building maps to monitor forest degradation/restoration

AKA forest land remaining forest land



Building maps to monitor forest degradation/restoration

- Examples include: logging, grazing, fine-grain settlement
- Degradation is scale-dependent
- Can this include clear-felling?

Change maps built using same procedures as described for forest/non-forest

GOFC-GOLD describes two approaches to monitoring the conversion of intact to non-intact forest

- Indirect (section X.X.X)
  wherein geographic information relating to human activity is used to identify areas likely effected
- Direct (section X.X.X)
  wherein canopy disturbances are actually identified with imagery

Indirect Approach

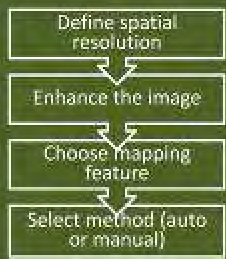
Exclude from Intact forest classification:

First, areas around human settlements

Second, areas around roads

Direct Approach

GOFC-GOLD identifies these steps:
(section 2.1.3)



Technical requirements recap

Image Acquisition
- *Internet access for Landsat and air photos*
- *1 TB more than enough for image storage*

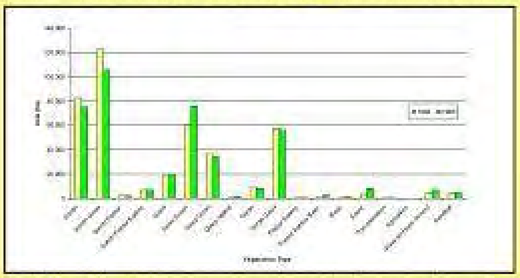
Software requirements
- *Imagine™ and ArcMap™*
- *Public domain software may exists too*

Technical expertise
- *Only basic skills required, but steep learning curve*
- *Short training courses available*

Expert Knowledge
- *No substitute for local knowledge*
- *Some statistical expertise for error propagation*

Runkel and Ahmad 1997

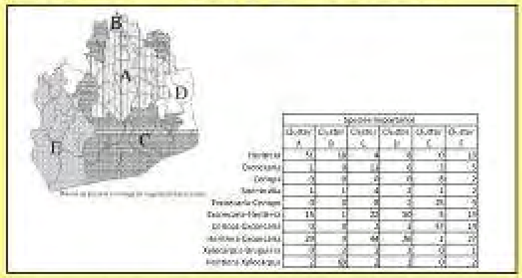
Change in forest cover class through air photo interpretation



Runkel M. and I. Ahmad (1997). Sundarbans Reserved Forests Area, Distribution and Status of Forest Types from 1985 to 1995. Geographic Resource Information Management System (RIMS-GIS) of the Forest Department Bangladesh.

Iftekhar and Saenger 2008

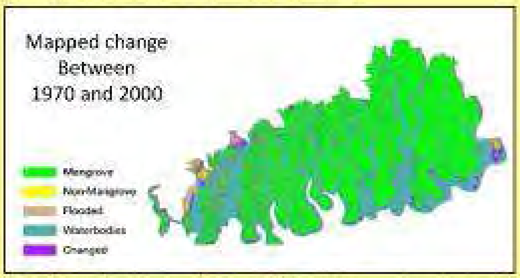
Using stem-level inventory to identify forest classes



Iftekhar, M.S. and P. Saenger (2008) Vegetation dynamics in the Bangladesh Sundarbans mangroves: a review of forest inventories. *Wetlands Ecology Management*. 16:291–312.

Giri and others 2007

Change detection using Landsat imagery



Giri, C. B. Pengra, Z. Zhu, A. Singh, and L. Tieszen (2007) Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. *Estuarine, Coastal and Shelf Science*. 73: 91-100.

Satyanarayana and others 2001

Mapping biomass as a continuous variable (in Coringa)

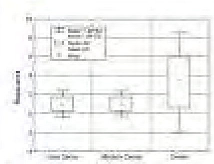


Figure 4: Comparison of basal area mean for the three mangrove classes

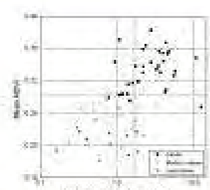
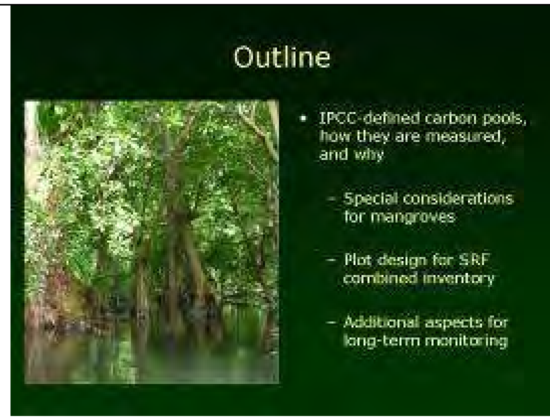
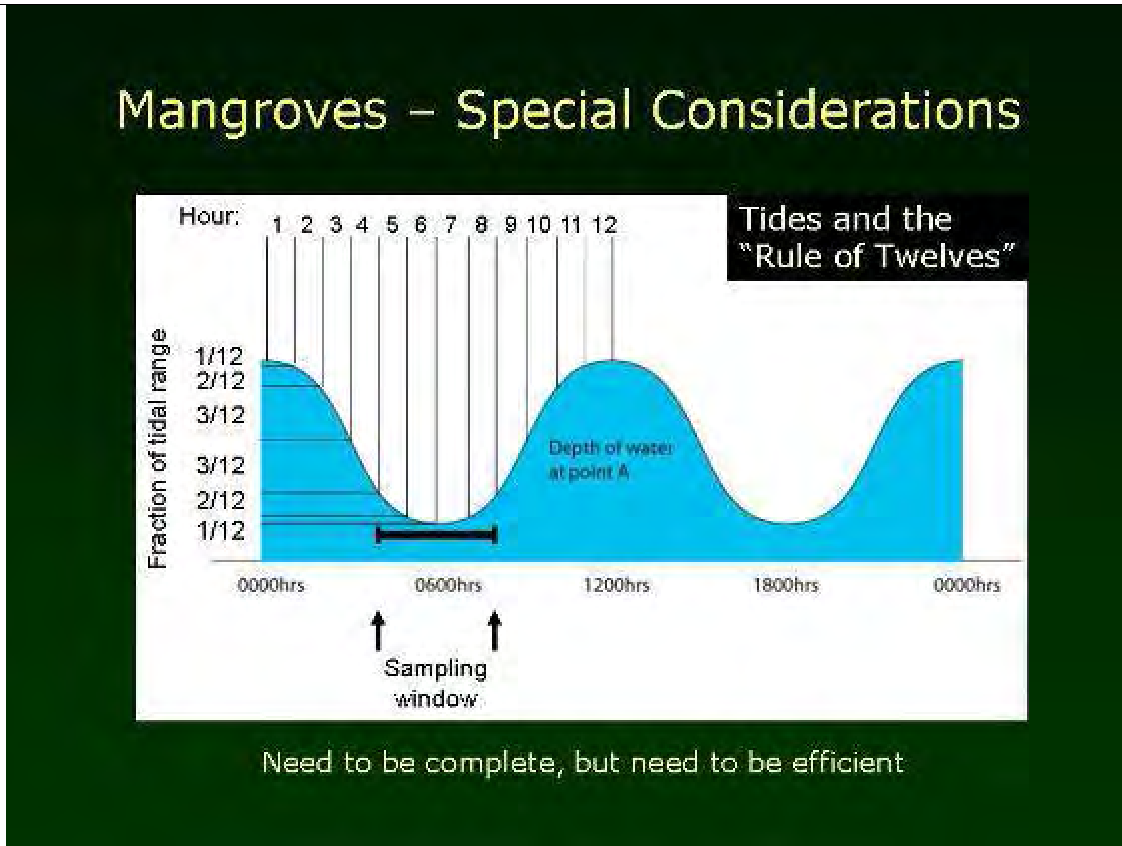


Figure 5: Basal area vs. NDVI for the three mangrove classes

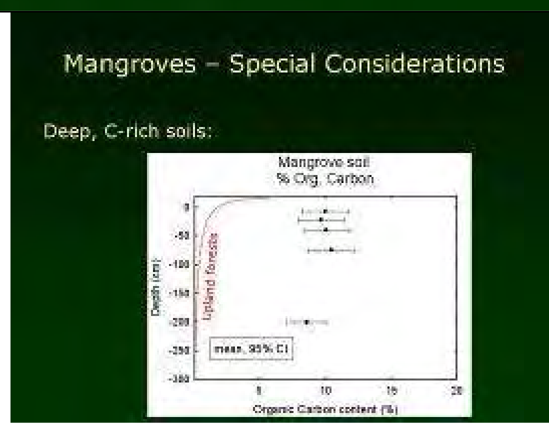
Satyanarayana, B., D. Thierry, D. LoSeen, A.V. Raman, and G. Muthusankar (2001). Remote sensing in mangrove research- relationship between vegetation indices and dendrometric parameters: a case for Coringa, east coast of India 22[nd] Asian Conference on Remote Sensing. Center for remote sensing and processing. National University of Singapore

PRESENTATION 13: MEASURING FOREST CARBON POOLS. D.C. DONATO, M.A. STIDHAM, J.B. KAUFFMAN, USFS



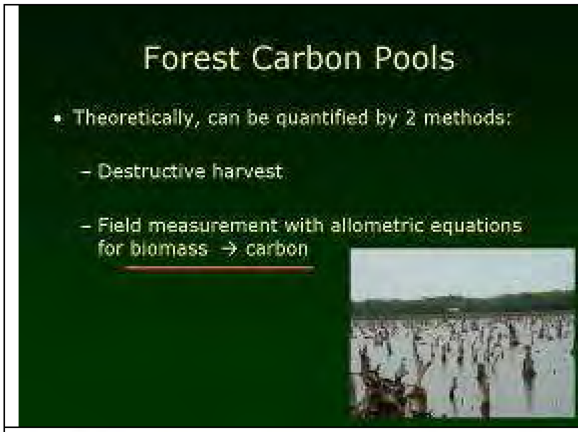

Mangroves – Special Considerations
Hour:
1 2 3 4 5 6 7 8 9 10 11 12
Tides and the
"Rule of Twelves"
Fraction of tidal range
1/12
2/12
3/12
3/12
2/12
1/12
Depth of water at point A
0000hrs
0600hrs
1200hrs
1800hrs
0000hrs
Sampling window
Need to be complete, but need to be efficient


Mangroves – Special Considerations

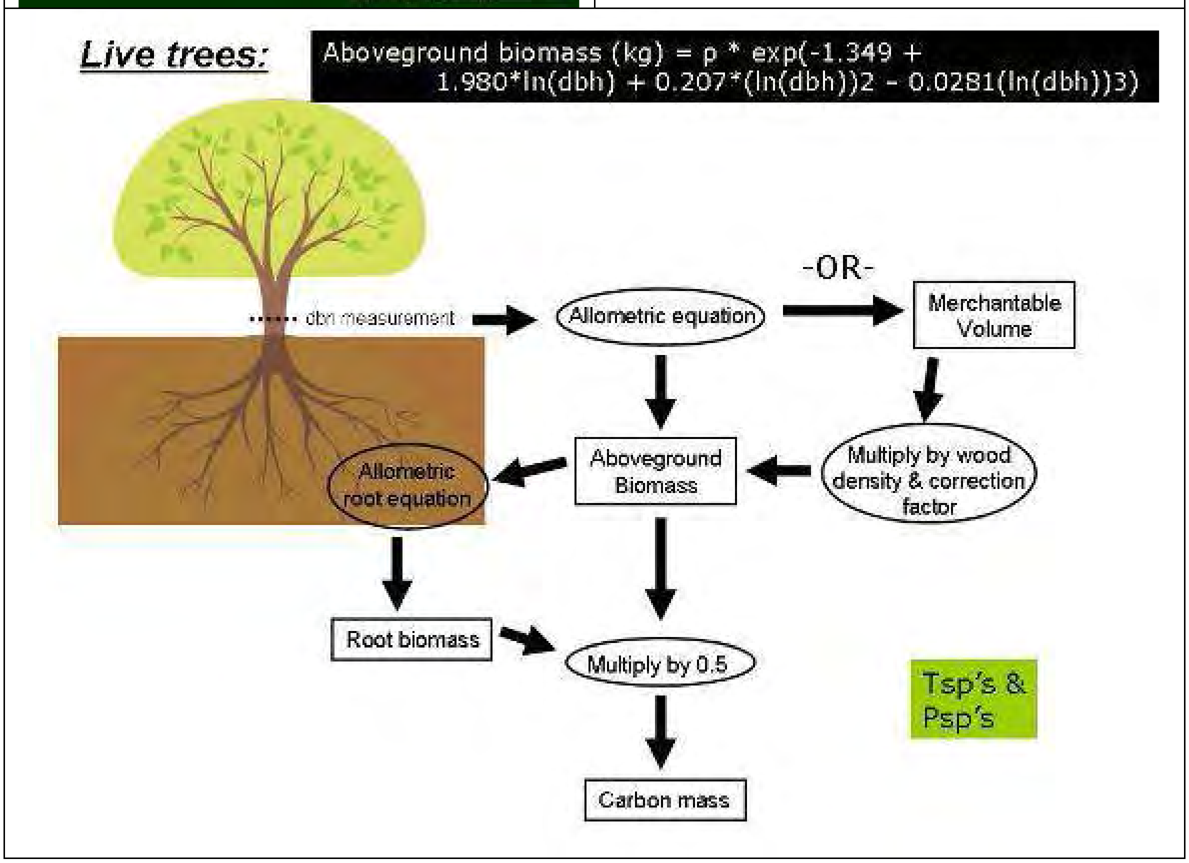

Mangroves – Special Considerations
Deep, C-rich soils:
Mangrove soil
% Org. Carbon
Upland forests
mean, 95% CI
Organic Carbon content (%)

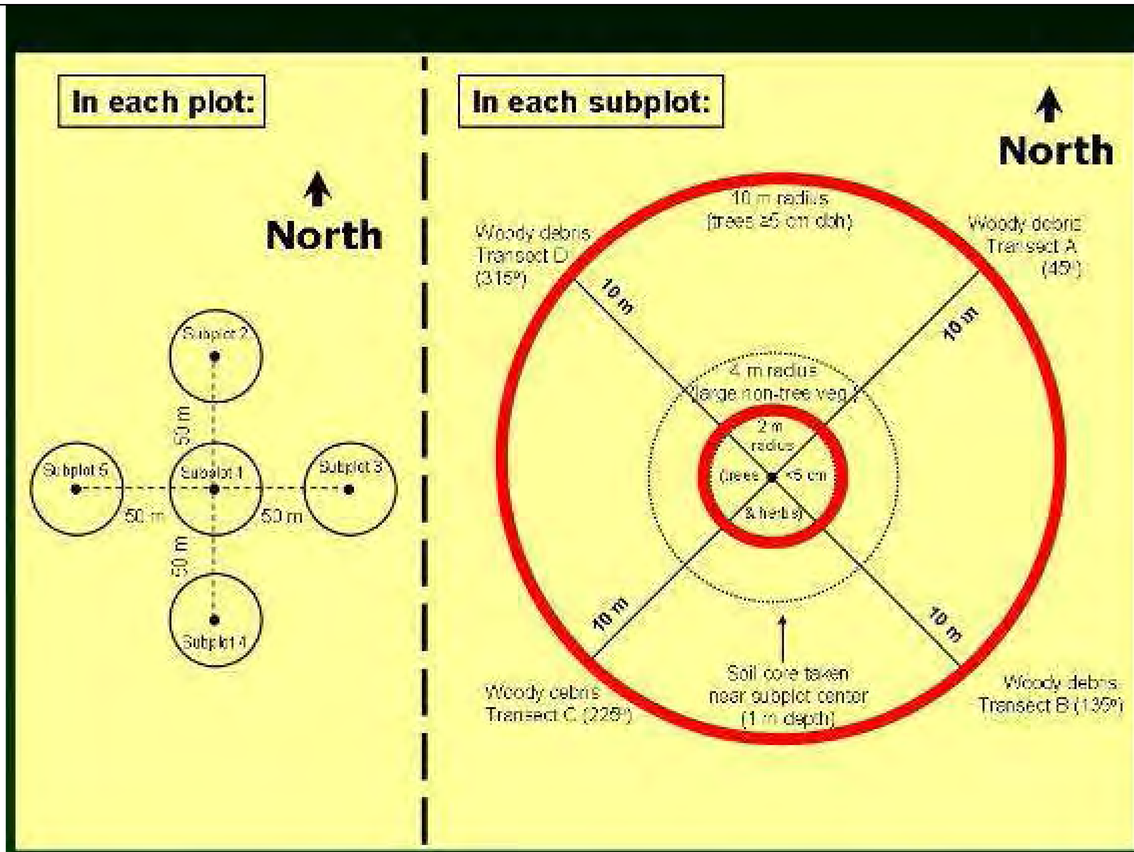

IPCC-defined
Carbon Pools

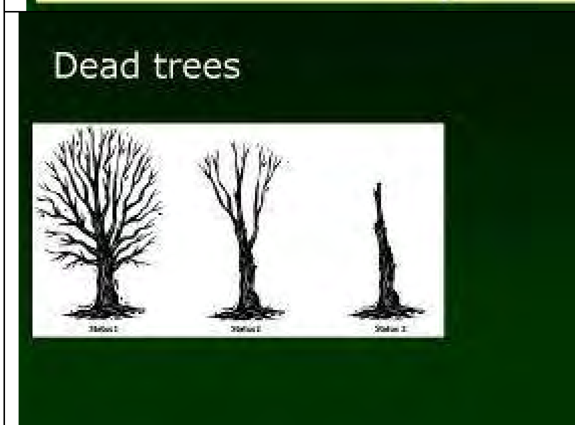

Trees
Non-tree vegetation
Dead wood
Soil
Forest floor

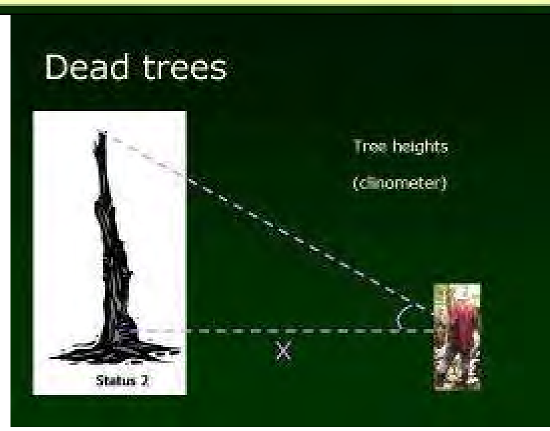

Forest Carbon Pools
• Theoretically, can be quantified by 2 methods:
– Destructive harvest
– Field measurement with allometric equations for biomass → carbon

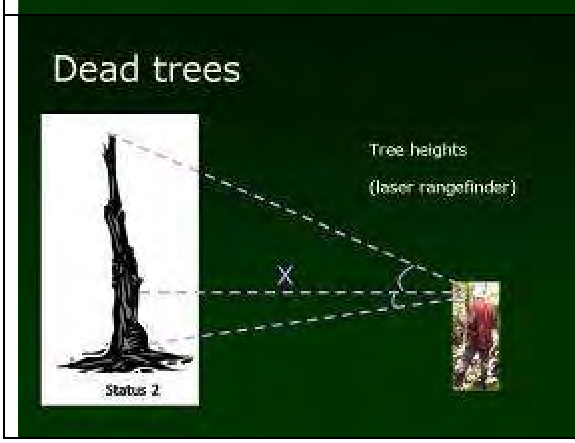

Trees


Live trees:
Aboveground biomass (kg) = p * exp(-1.349 + 1.980*ln(dbh) + 0.207*(ln(dbh))2 - 0.0281(ln(dbh))3)
dbh measurement
Allometric equation
-OR-
Merchantable Volume
Multiply by wood density & correction factor
Aboveground Biomass
Allometric root equation
Root biomass
Multiply by 0.5
Carbon mass
Tsp's & Psp's


In each plot:
North
Subplot 2
Subplot 5
Subplot 1
Subplot 3
Subplot 4
50 m
50 m
50 m
50 m
In each subplot:
North
10 m radius
(trees ≥5 cm dbh)
Woody debris
Transect D
(315°)
Woody debris
Transect A
(45°)
10 m
10 m
10 m
10 m
4 m radius
(large non-tree veg.)
2 m
radius
(trees <5 cm
& herbs)
Soil core taken
near subplot center
(1 m depth)
Woody debris
Transect C (225°)
Woody debris
Transect B (135°)


Dead trees

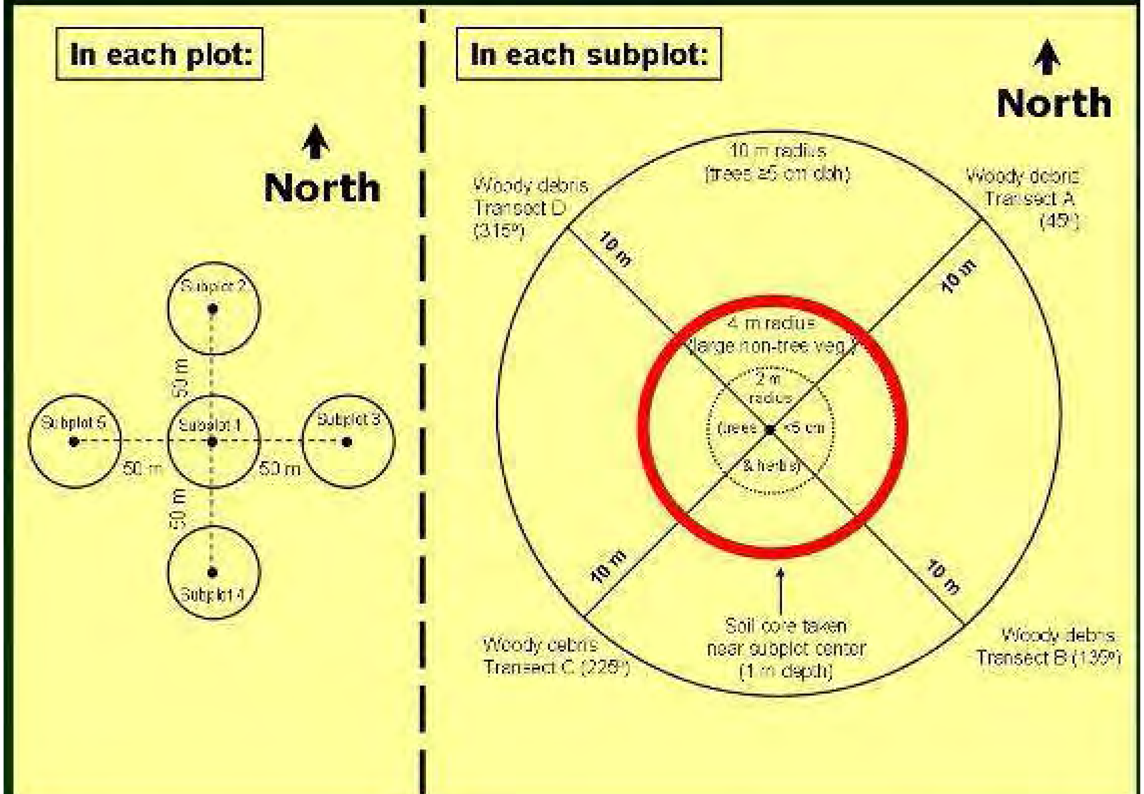

Dead trees
Tree heights
(clinometer)
X
Status 2


Dead trees
Tree heights
(laser rangefinder)
X
Status 2


Non-tree
vegetation

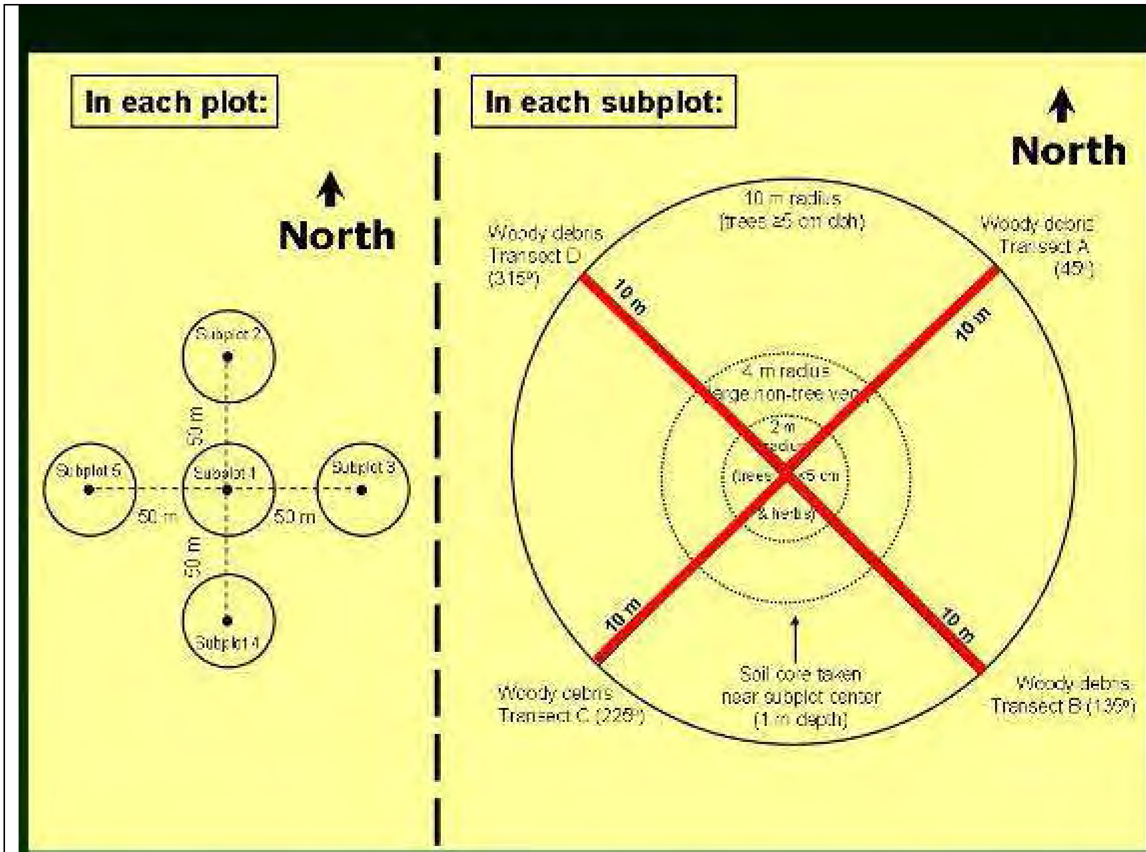
Non-tree vegetation

Measured as counts of individuals or stems → Scaled to biomass by using allometrics or average weights → Converted to C mass by multiplying by 0.5



In each plot:
North
Subplot 2
Subplot 5
Subplot 1
Subplot 3
Subplot 4
50 m
50 m
50 m
50 m
In each subplot:
North
10 m radius
(trees ≥5 cm dbh)
Woody debris
Transect D
(315°)
Woody debris
Transect A
(45°)
10 m
10 m
4 m radius
(large non-tree veg.)
2 m
radius
(trees <5 cm
& herbs)
10 m
10 m
Soil core taken
near subplot center
(1 m depth)
Woody debris
Transect C (225°)
Woody debris
Transect B (135°)

Dead wood



Dead wood

$$\text{Volume } (m^3\ ha^{-1}) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + d_3^2 + \dots d_n^2}{8 * L} \right)$$

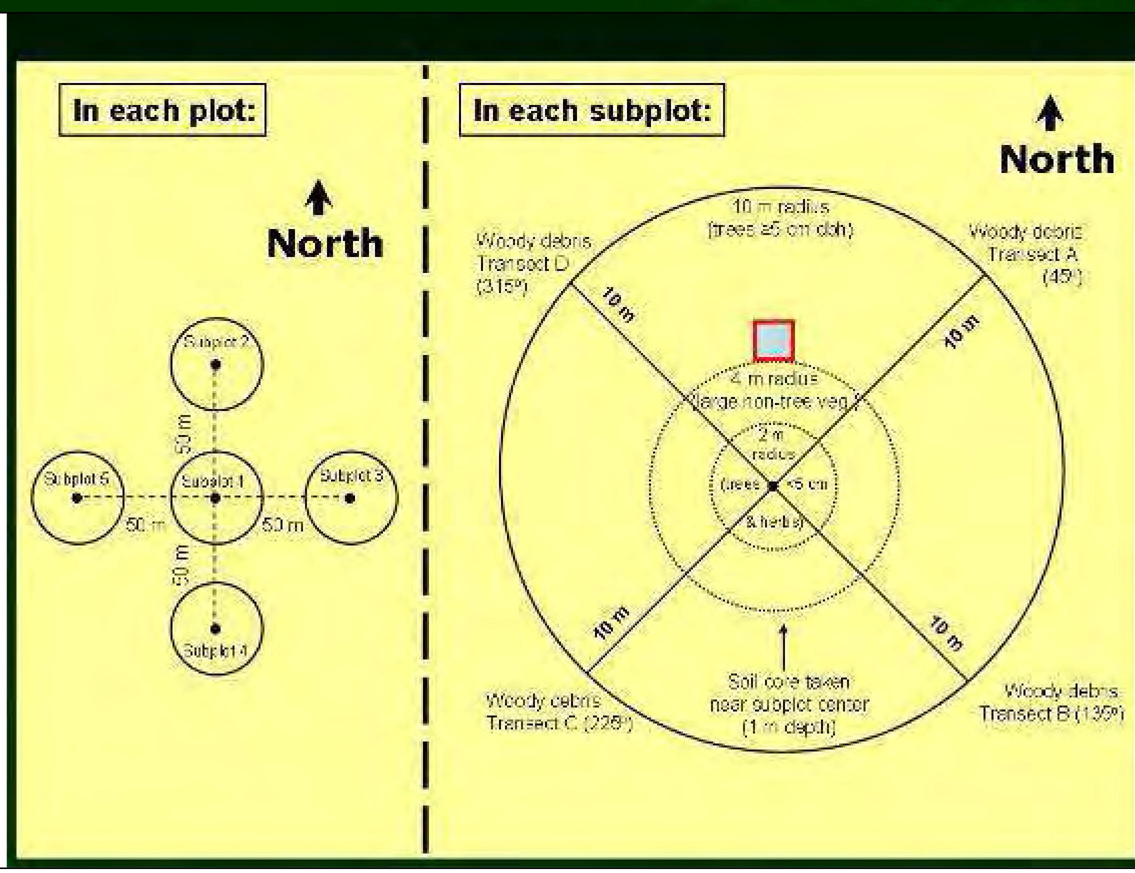
Measured using transects: Pieces crossing the line are tallied

Scaled to volume per area using geometric equation

Converted to biomass by multiplying by wood density

Converted to C by multiplying by 0.5


Forest Floor


In each plot:
North
Subplot 2
Subplot 5
Subplot 1
Subplot 3
Subplot 4
50 m
50 m
50 m
50 m
In each subplot:
North
10 m radius
(trees ≥5 cm dbh)
Woody debris
Transect D
(315°)
Woody debris
Transect A
(45°)
10 m
10 m
10 m
10 m
4 m radius
(large non-tree veg.)
2 m
radius
(trees <5 cm
& herbs)
Woody debris
Transect C (225°)
Soil core taken
near subplot center
(1 m depth)
Woody debris
Transect B (135°)


Soil

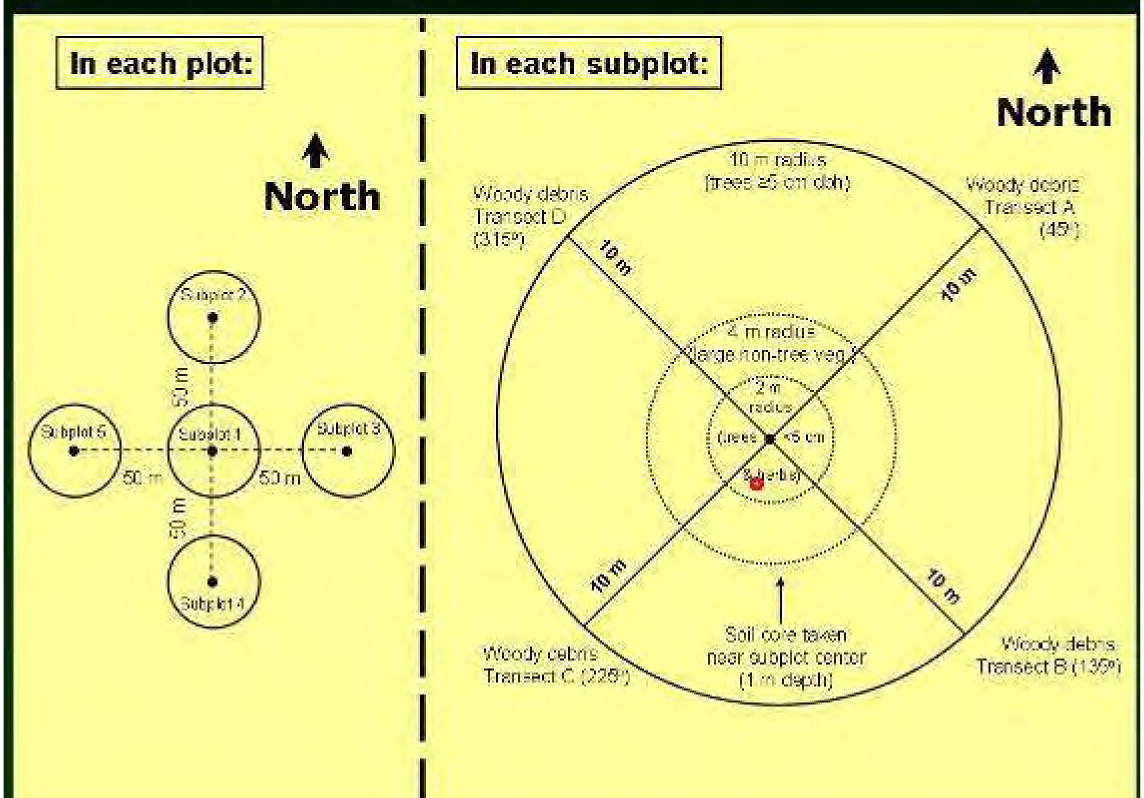

Soil
A
B
C
D
E
F

Soil

Two important parameters:

Soil Bulk Density (g cm^{-3})

% OC content



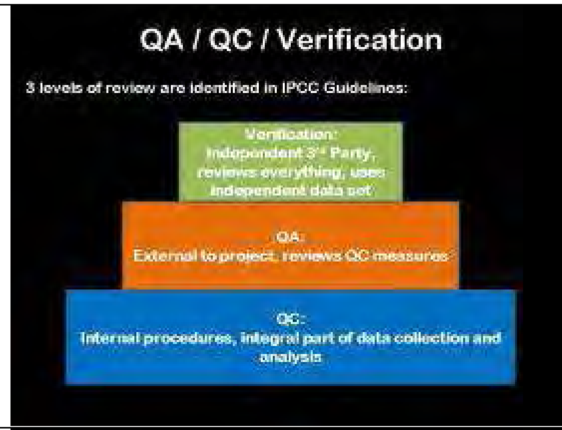

Other aspects for
long-term monitoring

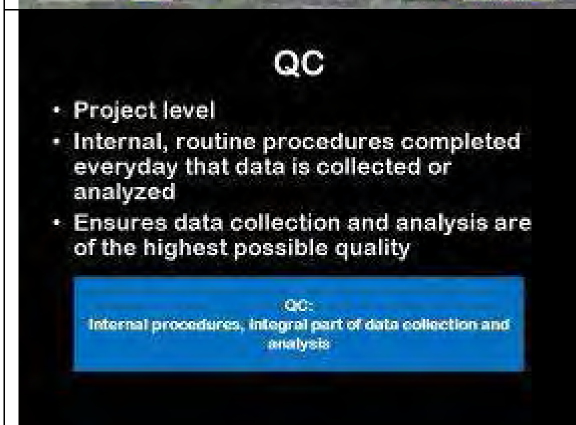

Tree heights
Using a laser range finder
Only a subset of trees (3 at each subplot)
Purpose:
To facilitate future monitoring via remote sensing tools (e.g. LIDAR, etc.)
So that diameter-height regressions can be built for all trees
Canopy cover
Using a densiometer
Purpose: To monitor forest canopy cover and to intersect with remote sensing data
Photo documentation
Systematic photopoints at center of each plot
Reporting purposes, visualization

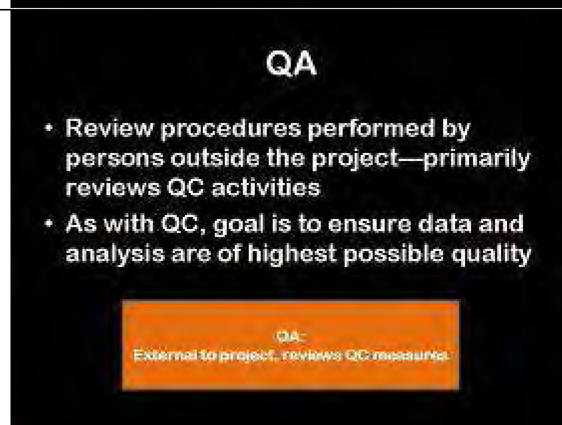

Project Technical Components
Generate an overall plan
Design sampling scheme
Sample the forest
Analyze the data
Report C stocks
Monitoring plan for future
Quality Assurance / Quality Control (QA/QC)

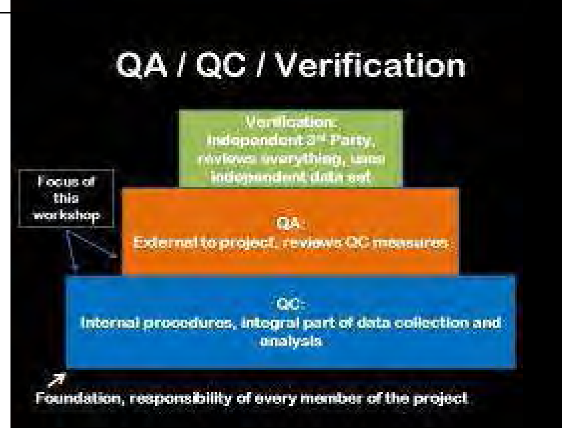

Thank you!
IPIF

PRESENTATION 14: QUALITY ASSURANCE / QUALITY CONTROL: BUILDING TRUST IN YOUR DATA M.A. STIDHAM, D.C. DONATO, J.B. KAUFFMAN, USFS









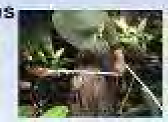
Purpose of QA/QC

Ensures all possible measures have been taken to guarantee high quality data have been collected and can be reproduced.

Very important part of the project; equally as important as data collection and analysis.

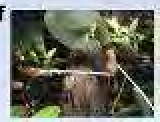
General elements of QA/QC

- QC includes:
  - Taking accurate, careful measurements in the field
  - Accurately recording the measurements in the field and in a database, *and* systematically checking for errors
  - Accurate and appropriate data analysis
  - Data management: procedures for data security and integrity



General elements of QA/QC

- QA includes:
  - Reviewing at least 10% of datasheets for clarity and completeness, and accuracy in entry into database
  - Bringing errors to attention of field supervisor and crew leader
  - Suggesting corrective procedures if needed (i.e., re-measurement)
  - More reviews may be needed if many errors are found



QC: Basic steps, data collection

- Field crew:
  - Taking accurate, careful measurements
  - Recording data in legible, complete, and accurate manner
  - Checking data recorded after every field outing—find and correct errors right away

QC: Basic steps, data entry

1. Entering data exactly into database

Datasheet:

Plot: Kumai 1 Date: 9/29/09 Recorder: Melanie Surveyors: Ivan Eric

Trees (7-m radius circle)

Subplot	Species	DBH	Dead (y)	Height if Dead	Subplot	Species	DBH	Dead (y)	Height if Dead
1	RHAP	29.3			1	XYGR	12.8		
1	RHAP	26.9			1	RHAP	21.2		
1	RHAP	19.8			1	BRGY	16.4		
1	RHAP	25.5			2	RHAP	25.6		

Database:

SortKey	Region	Site	Plot	Species	dbh	dead	height if deadbroken
1	Tanjung Puting	Kumai 1	1	RHAP	29.3		
2	Tanjung Puting	Kumai 1	1	RHAP	26.9		
3	Tanjung Puting	Kumai 1	1	RHAP	19.8		
4	Tanjung Puting	Kumai 1	1	RHAP	23.5		
5	Tanjung Puting	Kumai 1	1	XYGR	12.8		
6	Tanjung Puting	Kumai 1	1	RHAP	21.2		
7	Tanjung Puting	Kumai 1	1	BRGY	16.4		
8	Tanjung Puting	Kumai 1	2	RHAP	25.0		

QC: Basic steps, data entry

2. Checking every datasheet once entered into database for errors

Datasheet:

Plot: Kumai 1 Date: 9/29/09 Recorder: Melanie Surveyors: Dan, Eric

Trees (7-m radius circle)

Subplot	Species	DBH	Dead (y)	Height if Dead	Subplot	Species	DBH	Dead (y)	Height if Dead
1	RHAP	29.3			1	XYGR	12.8		
1	RHAP	26.9			1	RHAP	21.2		
1	RHAP	19.8			1	BRGY	16.4		
1	RHAP	25.5			2	RHAP	25.0		

Database:

SortKey	Region	Site	Plot	Species	dbh	dead	height if deadbroken
1	Tanjung Puting	Kumai 1	1	RHAP	29.3		
2	Tanjung Puting	Kumai 1	1	RHAP	26.9		
3	Tanjung Puting	Kumai 1	1	RHAP	19.8		
4	Tanjung Puting	Kumai 1	1	RHAP	23.5		
5	Tanjung Puting	Kumai 1	1	XYGR	12.8		
6	Tanjung Puting	Kumai 1	1	RHAP	21.2		
7	Tanjung Puting	Kumai 1	1	BRGY	16.4		
8	Tanjung Puting	Kumai 1	2	RHAP	25.0		

QC: Basic steps, data entry

3. Fixing found errors

Datasheet:

Plot: Kumai 1 Date: 9/29/09 Recorder: Melanie Surveyors: Dan, Eric

Trees (7-m radius circle)

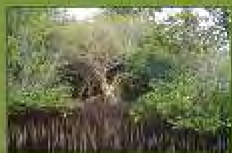
Subplot	Species	DBH	Dead (y)	Height if Dead	Subplot	Species	DBH	Dead (y)	Height if Dead
1	RHAP	29.3			1	XYGR	12.8		
1	RHAP	26.9			1	RHAP	21.2		
1	RHAP	19.8			1	BRGY	16.4		
1	RHAP	25.5			2	RHAP	25.0		

Database:

SortKey	Region	Site	Plot	Species	dbh	dead	height if deadbroken
1	Tanjung Puting	Kumai 1	1	RHAP	29.3		
2	Tanjung Puting	Kumai 1	1	RHAP	26.9		
3	Tanjung Puting	Kumai 1	1	RHAP	19.8		
4	Tanjung Puting	Kumai 1	1	RHAP	25.5		
5	Tanjung Puting	Kumai 1	1	XYGR	12.8		
6	Tanjung Puting	Kumai 1	1	RHAP	21.2		
7	Tanjung Puting	Kumai 1	1	BRGY	16.4		
8	Tanjung Puting	Kumai 1	2	RHAP	25.0		

QC: Basic steps, data analysis

- Review calculations to ensure they are correct, values are within a reasonable range, and when they are unexpected, verifying the result to make sure it is a real result instead of a mistake.



= X Mg C ha^{-1}

QC: Basic steps, reporting

- Review what was written to ensure it makes sense, values are correct, and has correct spelling and grammar
  - Mistakes at this level can call into question all previous steps

= X Mg C ha^{-1} = $

QA/QC Plan

- Internal document that covers all aspects of data collection, data analysis, and data management in order to meet the overall goals of:
  - Transparency
  - Consistency
  - Comparability
  - Completeness
  - Accuracy
  - Other data quality goals as appropriate to project

QA/QC Plan

QA/QC Activities

- Data collection
- Data recording
- Data entry
- Data management
- Data analysis
- Laboratory procedures
- Other

Plan Elements

- Tasks
- Roles and responsibilities
- Timelines
- Procedures to be taken when errors are found
- Documentation procedures

QA/QC Plan: Example

QA/QC Activity: Data Collection

Measurement of forest carbon pools

Plan Elements

- Tasks
- Roles and responsibilities
- Timelines
- Procedures to be taken when errors are found
- Documentation procedures

QA/QC Plan: Example

QA/QC Activity: Data Collection

Crew Leaders: safety of field crew members; implementation of consistent field methods for duration of project; organization/storage of datasheets while in field, etc

Crew members (data collectors): individual safety; taking careful, accurate measurements; checking that measurements are accurately recorded

Crew members (data recorders): individual safety; recording data in legible, complete, accurate manner; check datasheets everyday after field work for legibility, completeness and accuracy

Plan Elements

- Tasks
- Roles and responsibilities
- Timelines
- Procedures to be taken when errors are found
- Documentation procedures

QA/QC Plan: Example

QA/QC Activity: Data Collection

Everyday of data collection

Fix errors when found, bring to attention of data collectors or crew leader when needed. Re-measurement and/or re-training in field methods if needed.

Recorded on data sheets with name, data, and notes of any issues found and measures taken to correct.

Plan Elements

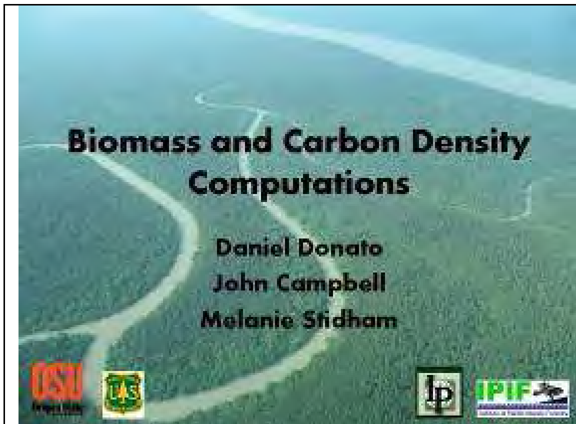
- Tasks
- Roles and responsibilities
- Timelines
- Procedures to be taken when errors are found
- Documentation procedures

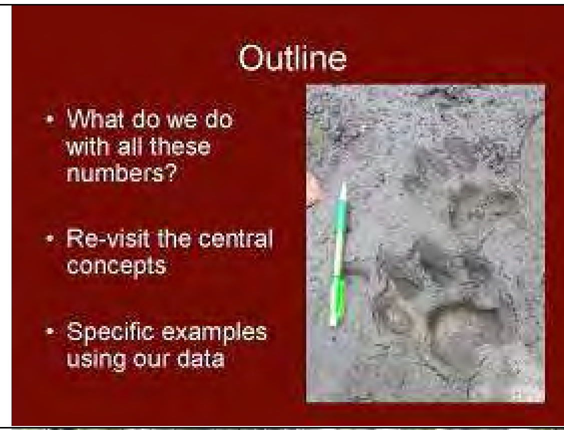
Data Management: a few points

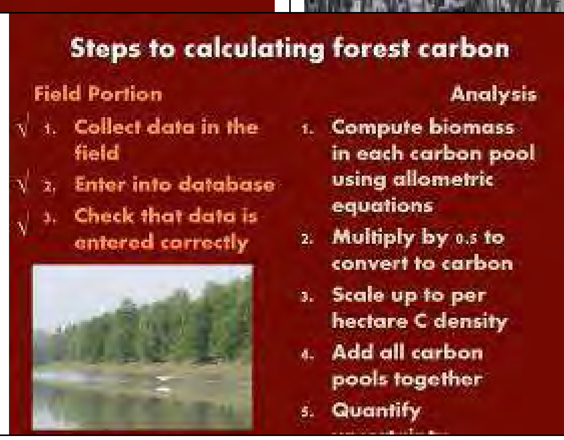
- Original datasheets organized and securely stored
- Copies of datasheets made and stored in alternate location
- Copies of database (clearly marked) stored in alternate location from original (i.e., laptop, external hard drive, flash drive, etc.)
- Final database made read-only and clearly labeled
- Analysis database separate from data entry database


Key Points:
• Develop QA/QC plan to address key project activities: data collection, data entry, data analysis, data management, and reporting
• Implement QC activities *and document them* everyday of field work, data entry and analysis
THANK YOU!
IPIF

PRESENTATION 15: BIOMASS AND CARBON DENSITY COMPUTATIONS D.C. DONATO, JOHN CAMPBELL, M.A. STIDHAM, USFS

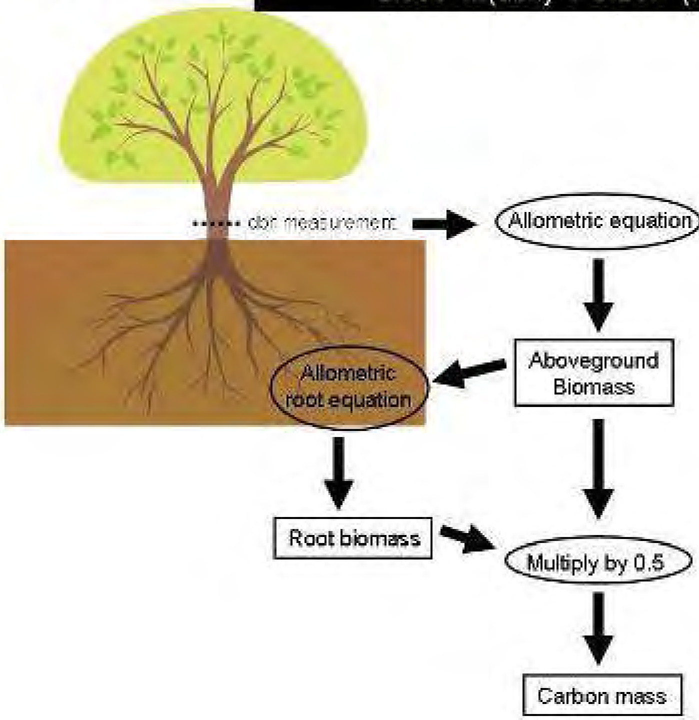




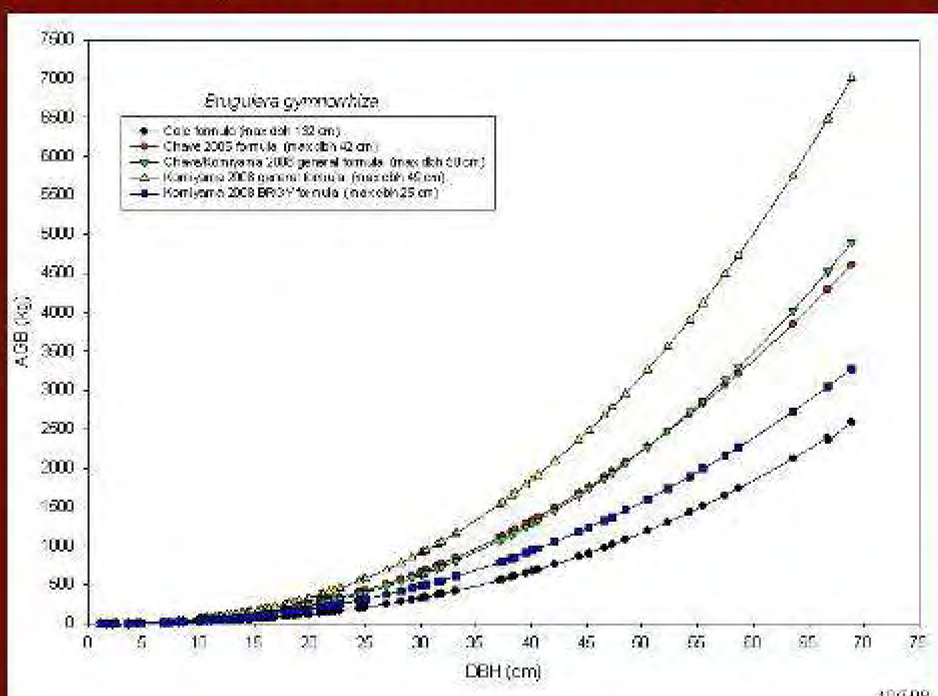


Live trees:

Aboveground biomass (kg) = ρ * exp(-1.349 + 1.980*ln(dbh) + 0.207*(ln(dbh))2 - 0.0281(ln(dbh))3)



Choosing an allometric equation



Wood densities

Table 3. Wood densities of common tree species of Sundarbans.

Scientific name	Four-letter species code	Common name	Wood density ($g\ cm^{-3}$)
Avicennia officinalis	AVOL	Baen	0.740
Bruguiera gymnorhiza	BRGY	Kankra	0.970
Ceriops decandra	CEDE	Goran	0.960
Excoecaria agallocha	EXAG	Gewa	0.490
Heritiera fomes	HEFO	Sundri	0.730
Sonneratia apetala	SOAP	Keora	0.700
Xylocarpus granatum	XYGR	Dhundul	0.700
Xylocarpus mekongensis	XYME	Passur	0.725
Site average of above values	na	Mean density	0.752

Note: These values are from the World Agroforestry Database (see text). If more site-specific values are available, use those instead.

Aboveground biomass (kg) = ρ * exp(-1.349 + 1.980*ln(dbh) + 0.207*(ln(dbh))2 - 0.0281(ln(dbh))3)

Tree example

Example: a Sundri tree with dbh of 22 cm and wood density of 0.730 would be entered as follows:

Biomass calculation:

Aboveground Biomass (kg) = ρ * exp(-1.349 + 1.980*ln(dbh) + 0.207*(ln(dbh))^2 – 0.0281(ln(dbh))^3)

[Where ρ is wood density in $g\ cm^{-3}$, dbh is in cm]

Aboveground Biomass (kg) = 0.730 * exp(- 1.349 + 1.980*ln(22) + 0.207*(ln(22))^2 – 0.0281(ln(22))^3) = 271.6 kg

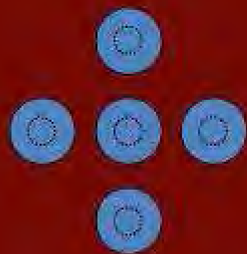
Convert to Mg:

Aboveground Biomass (Mg) = 271.6/1000 = 0.2716 Mg

Convert to carbon:

Aboveground C mass (Mg) = 0.2716 * 0.5 = 0.136 Mg C

Tree example -- Scaling to per hectare



Plot area (m^2) = $5 * (\pi * 10^2)$

= C mass per m^2

Scale to hectare by multiplying by 10,000 m^2 ha^{-1}

Example of tree C computation:

Sundri	0.136 Mg C	Scale to Mg per hectare:
Gewa	0.125 Mg C	
Liana	0.082 Mg C	[0.444 Mg C / ($5*3.14*10^2$)] * 10,000
Sundri	0.101 Mg C	
Plot Total =	0.444 Mg C	= 2.83 Mg C ha^{-1} of trees

Trees

>5cm dbh; 10 m radius circle

Sort Key	Plot	Sub-plot	Species	DBH (cm)	Dead (y)	Decay Status	Base Dia. Decay Stat. 2 (cm)	Height (m)	Mark x if box is checked: Sundri Top-Dying <50%	Sundri Top-Dying >50%	Timber Defect (% <50%	Timber Defect (% >50%
1	451	1	EXAG	6.2								
2	451	1	HEFO	15.2								
3	451	1	HEFO	11.0								
4	451	1	EXAG	7.5								
5	451	1	HEFO	10.5								
6	451	1	EXAG	10.1								

Aboveground biomass (kg) = ρ * exp(-1.349 + 1.980*ln(dbh) + 0.207*(ln(dbh))2 - 0.0281(ln(dbh))3)

ρ (wood density)	Biomass (kg)			Carbon Mass (Mg)		
	If live	If Decay Status 1	If Decay Status 2	If live	If Decay Status 1	If Decay Status 2
0.752	12.146			0.00607		
0.752	112.257			0.05613		
0.752	50.230			0.02511		
0.752	19.414			0.00971		
0.752	44.741			0.02237		
0.752	40.621			0.02031		

Multiply by 0.5, and divide by 1000 = Mg C

Plot totals (live)

Plot	total carbon mass (Mg)	total carbon mass (Mg/Ha)
451	7.74	49.28
9999	17.52	111.60
9998	9.66	61.53

Plot totals (dead)

Plot	total carbon mass (Mg)	total carbon mass (Mg/Ha)
451	0.004	0.03
9999	0.004	0.02
9998	0.000	0.00

Sum by plot = Total tree Mg C

Divide by plot area, multiply by 10,000 m^2 ha^{-1}

Dead trees

Status 1: Calculated as for live trees, multiplied by 0.975 to account for leaf loss

Dead trees

Status 2: Calculated much differently

Dead trees

Taper Equation:

$$d_{top} = d_{base} - \left[100 * ht * \left(\frac{d_{base} - dbh}{130} \right) \right]$$

d_{top} = estimated diameter at top of tree (cm)
d_{base} = the measured basal diameter (cm)
ht = tree height (m)
dbh = tree dbh (cm)

Equation for volume of decay status 2 trees:

$$\text{Volume (cm}^3) = \left(\frac{\pi * (0.01 * ht)}{12} \right) * (d^2_{base} + d^2_{top} + (d_{base} * d_{top}))$$

ht = tree height (m)
d_{base} = the basal diameter (cm)
d_{top} = the diameter at the top (cm) estimated from the taper equation (if taper equation results in negative number, use 0 for d_{top}).


Status 2

Dead tree biomass (g) = volume (cm^3) * wood density ($g\ cm^{-3}$)

Belowground tree biomass

Equation for tree belowground biomass density:

$$BBD = \exp(-1.0587 + 0.8836 * \ln(ABD))$$

BBD = belowground biomass density ($Mg\ ha^{-1}$)
-1.0587 = constant
0.8836 = constant
ABD = aboveground biomass density ($Mg\ ha^{-1}$). Obtain ABD by multiplying aboveground tree C density ($Mg\ ha^{-1}$) by 2.

Multiply BBD by 0.5 to obtain C mass.

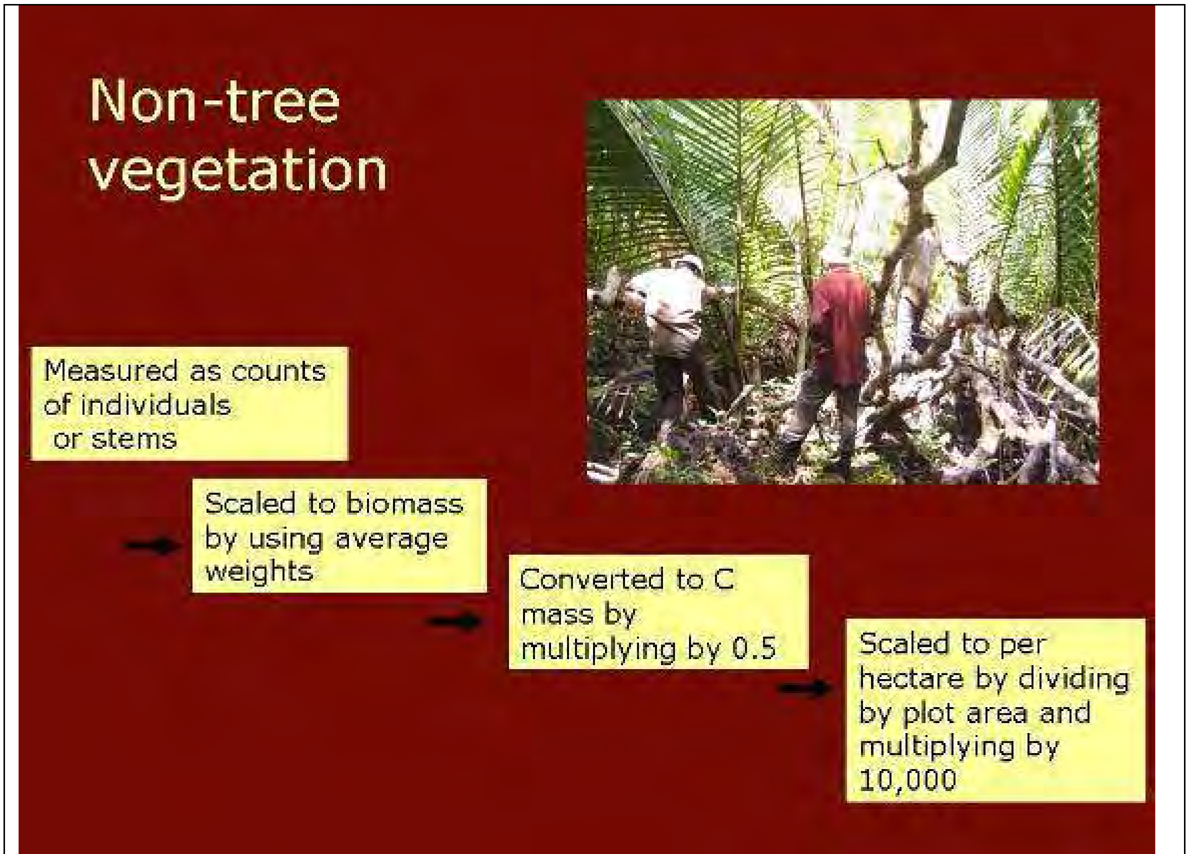
No scaling is necessary since the aboveground biomass value is already scaled to the hectare.

Example of belowground tree computation:
Aboveground C density = 120 $Mg\ ha^{-1}$
Aboveground Biomass Density (ABD) = 120 * 2 = 240 $Mg\ ha^{-1}$

BBD = exp(-1.0587 + 0.8836*ln(240))

BBD = 44.0 $Mg\ ha^{-1}$

Belowground C density = 44 * 0.5 = 22 $Mg\ ha^{-1}$


Non-tree vegetation
Measured as counts of individuals or stems
Scaled to biomass by using average weights
Converted to C mass by multiplying by 0.5
Scaled to per hectare by dividing by plot area and multiplying by 10,000


Dead wood

Dead wood

$$\text{Volume } (m^3\ ha^{-1}) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + d_3^2 + \ldots d_n^2}{8 * L} \right)$$

Woody Debris Biomass (Mg ha^{-1}) = Volume (m^3 ha^{-1}) * Wood density (g cm^{-3})

Transect tape

Measured using transects: Pieces crossing the line are tallied

→ Scaled to volume per area using geometric equation

→ Converted to biomass by multiplying by wood density

→ Converted to C by multiplying by 0.5

→ Averaged across all transects within plot

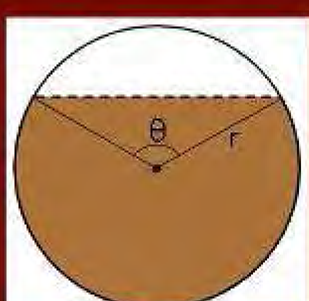
Soil

-Bulk density

- C content

Equation for soil bulk density:

$$\text{Soil bulk density (g m}^{-3}) = \frac{\text{Oven-dry sample mass (g)}}{\text{Sample volume (m}^3)}$$



$$5 * \text{Sample length collected} * \left(\pi * r^2 - \left(\frac{r^2}{2} * \left(\frac{\pi}{180} \theta - \sin \theta \right) \right) \right)$$

$$5 * 0.05 * \left(\pi * 0.0275^2 - \left(\frac{0.0275^2}{2} * \left(\frac{\pi}{180} * 119.5 - \sin(119.5) \right) \right) \right)$$

0.0003833 m^3

Soil

Equation for soil carbon per hectare:

Soil C (Mg ha^{-1}) = bulk density (g m^{-3}) * soil depth interval (m) * %OC * 0.01

Soil depth interval = 0.3 for 0-30 cm depth interval, and 0.7 for 30-100 cm interval
%OC is expressed as a decimal fraction (e.g., 5% is expressed as 0.05)
0.01 = a conversion factor to convert units to Mg ha^{-1}

Summing all the C pools

- First, calculate the mean carbon density (Mg ha^{-1}) for each component pool (e.g., trees, soil, etc.)
  → sum the C density (Mg ha^{-1}) of a pool across all inventory plots and divide by the number of plots

- Total carbon density is estimated by summing the mean carbon density for all component pools across the study area in Mg ha^{-1}

Equation for total carbon density:

Total C density (Mg ha^{-1}) =

C[illegible] + C[illegible] + C[illegible] + C[illegible] + C[illegible] + C[illegible] + C[illegible] + C[illegible] + C[illegible]

Easy quality check: Is it reasonable?

Total C stock in project area

Equation for total carbon stock of a given project area:

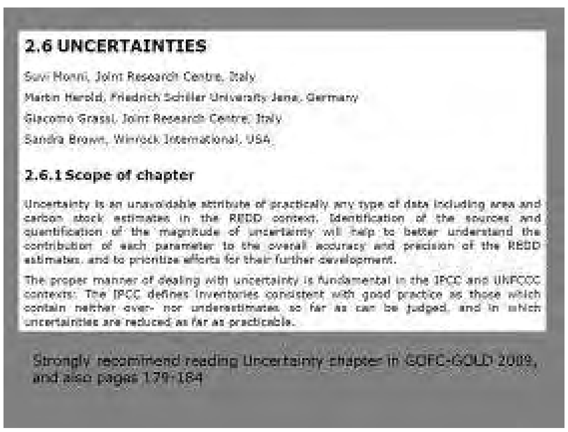
Total carbon stock of SRF (Gg) = Total C density (Mg ha^{-1}) * Area$_{SRF}$ (ha) * 0.001

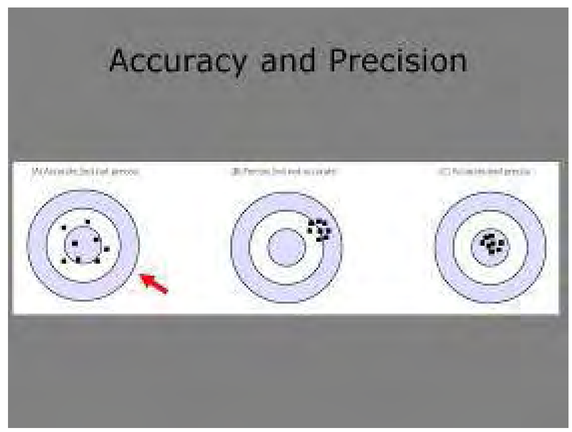
Converting to CO_2 equivalents

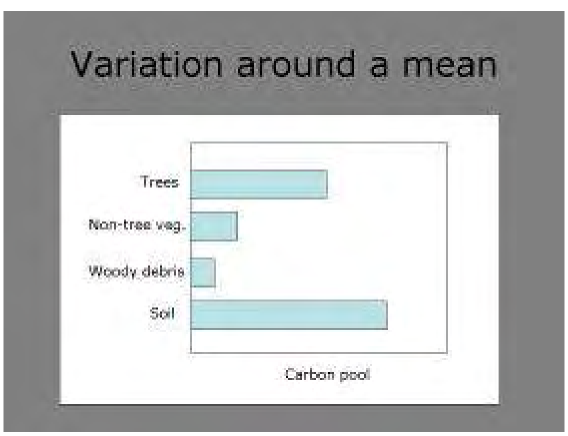
Equation for converting total carbon stock to CO_2 equivalents:

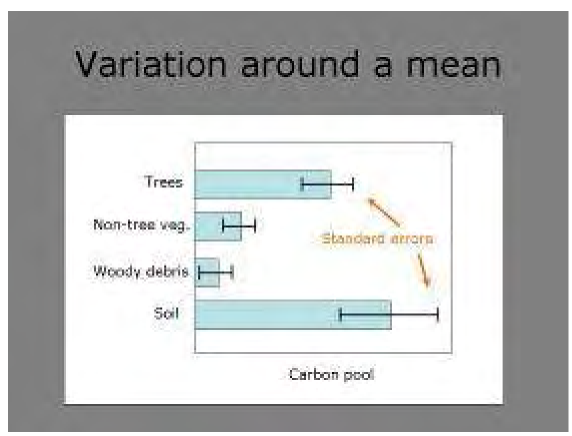
Total C stock (Gg CO_2 equivalents) = 3.67 * [total C stock (Gg C)]

PRESENTATION 16: QUANTIFYING UNCERTAINTY. D.C. DONATO, JOHN CAMPBELL, M.A. STIDHAM, USFS









Computing the standard error

Equation for standard deviation of a mean:

$$\text{Standard deviation of the mean } (s) = \sqrt{\sum_{i=1}^{n} (Y_i - \bar{Y})^2 \Big/ (n-1)}$$

Y_i = value of the ith plot,
$\bar{Y}$ = mean value of all plots,
n = the number of plots.

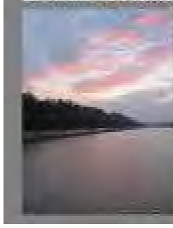
Equation for standard error of a mean:

$$\text{Standard error of the mean (SE)} = \frac{s}{\sqrt{n}}$$

s = standard deviation of mean,
n = number of plots

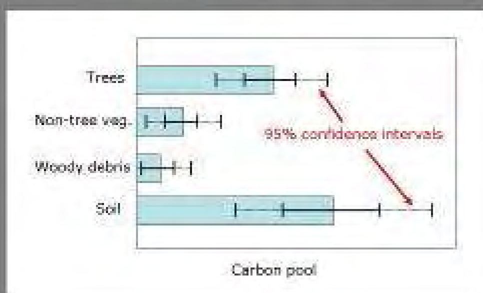
95% Confidence Intervals

Confidence interval is a range that encloses the true value of an unknown parameter with a specified confidence (probability). In the context of estimation of emissions and removals under the UNFCCC, a 95% confidence interval is normally used. The 95 percent confidence interval has a 95 percent probability of enclosing the true but unknown value of the parameter. The 95 percent confidence interval is enclosed by the 2.5th and 97.5th percentiles of the probability density function.

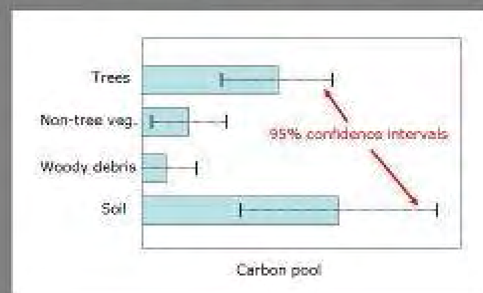


95% CI half-width = 2 * SE

95% confidence intervals



95% confidence intervals



95% confidence intervals

Often expressed as a percentage of the mean:

Uncertainty (%) = 100* (95% CI half-width) / mean.

Example:

Mean = 200 Mg ha^{-1}
S.E. = 20 Mg ha^{-1}
95% CI half-width= 40 Mg ha^{-1}

Uncertainty = 100* (40/200)
= 20%

Uncertainty in Total C Density

Total C density is sum of several pools

→ Uncertainty must also be "summed"

Termed "Error Propagation" or "Uncertainty Propagation"

Two Methods:
1) Simple error propagation
2) Monte Carlo method

Uncertainty in Total C Density

Simple error propagation

Equation for uncertainty in total carbon density:

$$\text{95\% CI half-width for total C density} = \sqrt{([95\%CI_1]^2 + [95\%CI_2]^2 + \ldots\ldots\ldots [95\%CI_n]^2)}$$

Where $[95\%CI_1]$ is the 95% CI half-width for pool 1, e.g., tree C mass, pool 2, and so on for all pools measured in the plots.

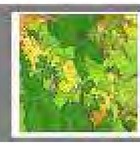
Uncertainty in Activity Data

2.6.3.1.1 Sources of error

Different components of the monitoring system affect the quality of the outcomes. They include:

- the quality and suitability of the satellite data (i.e. in terms of spatial, spectral, and temporal resolution),
- the interoperability of different sensors or sensor generations
- the radiometric and geometric preprocessing (i.e. correct geolocation),
- the cartographic and thematic standards (i.e. land category definitions and MMU)
- the interpretation procedure (i.e. classification algorithm or visual interpretation)

...etc....



Uncertainty in Total C Stock

Multiplicative equation

Equation for total carbon stock of a given project area:

Total carbon stock of SRF (Gg) = Total C density (Mg ha^{-1}) * Area (ha) * 0.001

Equation for uncertainty in total carbon stock:

$$\text{95\% CI half-width for total C stock} = \text{area} * \text{TCD} * \sqrt{([95\%CI_{area}/\text{area}]^2 + [95\%CI_{TCD}/\text{TCD}]^2)}$$

Area = estimated land area in a given category (e.g. forest),
TCD = mean total carbon density within that category,
$95\%CI_i$ = the uncertainty of each parameter (expressed as 95%CI half-width).

ANNEX IV: PROTOCOLS

Protocols for Measuring & Reporting Carbon Stocks in Mangrove Forests

With Special Reference to Carbon Assessment for Sundarbans Reserve Forest, Bangladesh

October 2009

Prepared by:

Daniel C. Donato, J. Boone Kauffman, and Melanie Stidham

U.S.D.A. Forest Service
Pacific Southwest Research Station
Northern Research Station
International Programs

Funding support from U.S.A.I.D. / Bangladesh

Purpose and Scope

The United States Agency for International Development (U.S.A.I.D.)/Bangladesh has enlisted the assistance of the U.S.D.A. Forest Service to provide technical expertise in the area of carbon estimation in wetland forests. This cooperative agreement aims to build in-country capacity for measuring, monitoring, and reporting carbon stocks in wetland forests, with special attention to the Sundarbans Reserve Forest (SRF)—part of the largest contiguous mangrove in the world. A specific objective is to establish a plan for a combined carbon and resource inventory of the SRF to support: a) entry into global carbon markets, and b) an updated forest management plan.

This document outlines the rationale, design, field measurement, analysis, and reporting required for forest carbon assessments. The focus is on mangroves but, with minor adaptations, the approaches generally apply in other wetland forests as well. Further, most of the general principles and approaches presented here apply to any forest type.

Although there are a number of suitable methods for measuring forest carbon stocks, the focus here is to adapt international standards per guidelines of the Intergovernmental Panel on Climate Change (IPCC) and relevant sourcebooks. The aim is to provide instruction on field measurements and computations that will support entry into regulatory or voluntary carbon markets at a high tier. However, it should be noted that the technical aspect of quantifying forest carbon is but one of several elements of carbon accounting schemes. These other important elements include social, political, and economic factors—for example, addressing permanence, leakage, governance, etc.—and are not covered here. Definitions and information on those topics can be found in the IPCC guidelines and associated sourcebooks.

Essential Sources

Several sourcebooks provide the specific field methods and computations presented here, including GOFC-GOLD (2009), Pearson et al. (2005), Pearson et al. (2007), and the IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry (2003) and IPCC Guidelines for National Greenhouse Gas Inventories (2006). These sources are relied on heavily here and several passages are inserted directly from them. Nevertheless, modification of these guidelines is necessary in some cases due to the uniquely challenging nature of sampling mangrove forests.

International guidelines and standards for carbon inventories evolve over time. Many of the relevant sourcebooks are ‘living documents’ that change as guidelines and standards change. Moreover, these documents contain significantly greater detail on options and rationale for carbon monitoring methodologies. These large documents have been distilled here based on the authors’ experience quantifying carbon in Asian-Pacific mangrove forests. Therefore, it is important for project personnel to read and keep current on these guideline documents (see References for detailed citations).

Introduction

The general principle of a forest carbon project is to reduce greenhouse gas emissions (e.g., carbon dioxide, or CO_2) from the forest sector. Forests store carbon, and deforestation and forest degradation in developing countries currently account for nearly 20% of global greenhouse gas emissions. Thus, reducing these trends may help mitigate climate change, in addition to conserving other ecosystem services provided by forests.

Carbon markets, in which payments are made to governments or other organizations for conserving forest carbon, are considered a promising mechanism where objectives include reducing deforestation and degradation. These markets come in various forms (e.g., regulatory versus voluntary), but most have some basic principles in common. Most relevant to this protocol is that carbon storage/emissions over a project area must be quantified for three time periods: the past, the present, and the future.

The past rate of carbon loss from the project area is estimated (e.g., for the past 10-20 years), the current carbon stock is estimated, and the future trend in carbon storage is projected based on the historic deforestation/degradation rate. The carbon project implements conservation measures that, ideally, reduce the rate of carbon loss compared to the historic rate, or the 'baseline.' Over time a monitoring program evaluates whether there has actually been any reduction in the rate of carbon loss. This difference, or 'additionality,' is the value traded in carbon markets.

This protocol emphasizes field methodologies for assessing current forest carbon stocks. However, the same analysis techniques apply to assessing past and future carbon stocks, thus allowing the use of ground data in support of all phases of a carbon project.

For the proposed carbon (C) assessment in the Sundarbans Reserve Forest (SRF), this document aims to provide a general conceptual background as well as specific, detailed instructions for the collection and analysis of field C data. Specific suggestions for overall sampling design, plot layout, and measurements are provided based on the authors' experience measuring C in Asian-Pacific mangroves. Other options are available and may well be perfectly adequate; these are mentioned in brief in this document. Project personnel may choose to adapt the specific methods according to their local knowledge, resource constraints, other data collection needs, or the evolving nature of IPCC and related sourcebook guidelines.

CONCEPTUAL BASIS

Tracking C Stocks, Deforestation & Forest Degradation

Carbon stocks are the combined storage of carbon in terrestrial ecosystems. In simplified terms, forest carbon accounting tracks changes in carbon stocks due to conversions between intact forests, non-intact (or degraded) forests, and other land uses (Figure 1). Relevant definitions are found in GOFC-GOLD (2009); the most important are repeated here from that source:

<u>Forest</u> is generally defined as having a minimum area of 0.05 – 0.1 hectare (ha), canopy height of 2 – 5 meters (m), and minimum tree crown cover of 10 – 30%. There is some flexibility in how countries define forest, depending on local circumstances. The Designated National Authority (DNA) in each country is responsible for the forest definition; a list of these authorities can be found online at http://cdm.unfccc.int/DNA. The Bangladesh DNA is:

Department of Environment
E/16 Agargaon,
Sher-e-Bangla Nagar,
Dhaka-1207,
Bangladesh

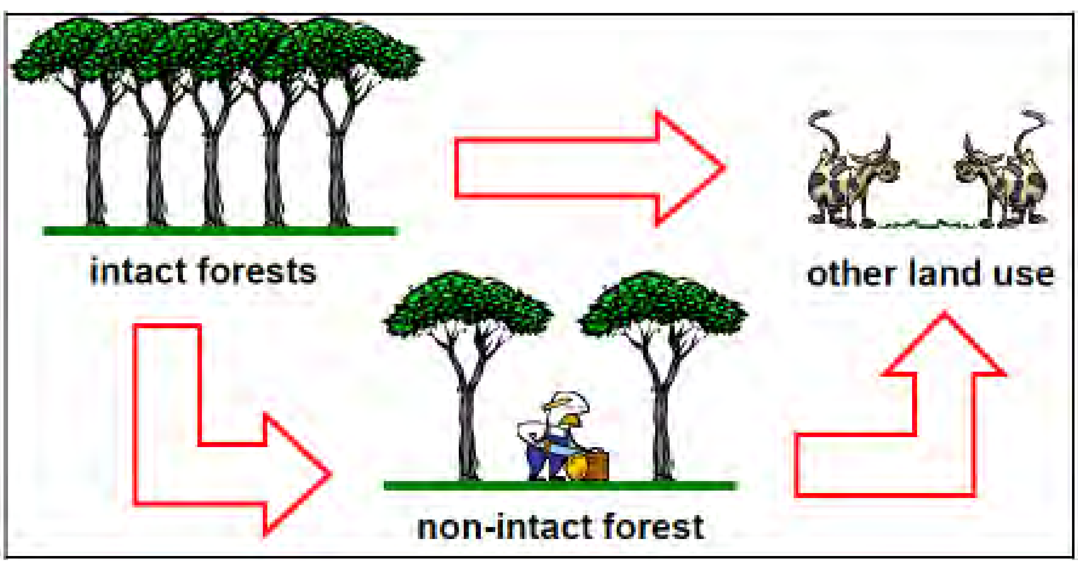


Figure 1. *Forest conversion types considered in a carbon accounting system. Adapted from GOFC-GOLD (2009). See text for definition of terms.*

Intact Forest: Fully stocked forest, undisturbed by timber extraction activities. Patches of forest that are not damaged or immediately surrounded by small clearings; forests without gaps caused by human activities.

Non-Intact Forest: Forest that meets at least the minimum criteria for 'forest' (see above), but is degraded by any of the following: canopy gaps created by logging operations, log landings where logs were stored and bare soil is exposed, logging roads which may be 3-15 m wide, etc. Not fully stocked.

Non-Forest (Other Land Use): Land not meeting the minimum criteria for forest cover.

Deforestation: Long-term or permanent conversion of land from forest to other non-forest uses.

Forest Degradation: General term for reductions in crown cover, tree density, or tree biomass (and thus carbon stock) that do not qualify as deforestation.

Two types of data:

Carbon inventorying requires two data types: activity data and emission factors. Activity data refer to the landscape coverage of different land uses, such as forest, agricultural land, grassland, or settlements, and the degree of transfer between them. For example, activity data may show that, during a certain time period, X number of hectares were converted from forest to agricultural land (deforestation). Activity data usually rely heavily on remote sensing analyses to classify land use types and to track changes between them over time. Activity data will be covered in the workshop but are not a primary focus of this protocol.

Emission factors refer to changes in various carbon pools of a forest. Changes may occur due to conversion between different land uses (e.g., deforestation from forest cover to agricultural land), or due to changes within a land use type (e.g., forest degradation due to selective logging). The methods in this document support the quantification and monitoring of emission factors based on ground data on carbon pools.

Generalized Steps to a Forest Carbon Accounting System

1. Establish the baseline (historic rate of reduction in forest carbon stocks due to deforestation and degradation)
2. Quantify current forest carbon stocks
3. Project future forest carbon stocks/emissions based on baseline rate (business as usual)
4. Monitor actual forest carbon stocks/emissions over time with conservation measures implemented; compare to baseline

This system requires both activity data and emission factors for past, present, and future time periods. Activity data is derived from remote sensing and other land cover information. Emission factors are derived from broad assumptions on carbon pools and their changes, or from field data on carbon stocks/emissions. Field data, which are the focus of this protocol, support higher tier (more precise, higher value) carbon assessments.

Tiers of Carbon Assessment

Carbon stock information can be assessed at different Tier levels (Table 1). Tier 1 uses IPCC default values (i.e., biomass in different forest biomes, etc.) and simplified assumptions; it may have a large error range of +/- 50% or more, or +/- 90% for the variable soil carbon pool. Tier 2 requires some country-specific carbon data for key factors. Tier 3 requires highly specific inventory-type data of carbon stocks in different pools, and repeated measurements of key carbon stocks through time, which may also be supported by modeling.

Table 1. *Summary of tiers that may be used to assess carbon (C) emission factors. Adapted from GOFC-GOLD (2009).*

Tier	Requirements
1	IPCC default factors
2	Country-specific data for key factors
3	Detailed inventory of key carbon stocks, repeated measurements of key stocks through time or modeling

In general, higher tiers increase the accuracy and precision of estimates. The IPCC recommends that countries should aspire for Tier 3 where possible, and that it is good practice to use higher tiers for the measurement of key carbon stocks/sources/sinks. Higher tiers produce more credible estimates and may support higher rates of carbon payment. On the other hand, Tier 3 is more costly to implement up front and is not always possible.

Tier 3 assessments may be most appropriate for the Sundarbans Reserve Forest. The area represents a large portion of Bangladesh forests, and likely represents a key terrestrial carbon stock or source for Bangladesh. In addition, the existing need for forest inventory data in support of an updated forest management plan already justifies an intensive field campaign (FD Bangladesh personnel, pers. comm.). The measurements required for a typical forest resource inventory and a Tier 3 carbon inventory are generally quite similar. Finally, an existing forest inventory plot grid in SRF provides an opportunity to leverage past data to compare historic and future carbon stocks and emissions.

Carbon assessments aim to estimate decreases in forest carbon stock, which is equated with emissions of CO_2 to the atmosphere. The two main approaches to this estimation are the stock-change approach and the gain-loss approach. The stock-change approach estimates the difference in carbon stocks at two points in time, while the gain-loss approach estimates the net balance of additions to and removals from a carbon stock. The stock-change approach is used when carbon stocks in relevant pools have been measured and estimated over time, such as in forest inventories. Thus, Tier 3 assessments often use stock-change methods. The gain-loss approach is used when annual data such as biomass growth rates and reliable data on wood harvests are available; these are more often used in Tier 1 and 2 assessments. However, in reality a mix of the two approaches may be part of any Tier assessment.

Note that, even if Tier 3 monitoring is not practical in the future due to financial constraints, establishing a credible benchmark estimate of carbon storage in a project area will allow future assessments to be conducted on at least a Tier 2 rather than Tier 1 level.

PROJECT DESIGN ASPECTS

Inventory and Reporting Principles

Good practice in carbon inventorying includes five general principles which should guide the estimation and reporting of forest C stocks and emissions: Transparency, Consistency, Comparability, Completeness, and Accuracy (GOFC-GOLD 2009).

Transparency – All assumptions and methodologies used in the inventory should be clearly explained, well justified, and appropriately documented, so that anybody could verify its correctness. All data should be well managed, tracked, and documented with meta-data (information explaining the data) to ensure transparency.

Consistency – The same definitions and methodologies should be used over time. This should ensure that differences between years and categories reflect real differences in emissions. Under certain circumstances, estimates using different methodologies for different years can be considered consistent if they have been calculated in a transparent manner. Thus, allowance is made for improvement of methods over time. The principle of consistency should be considered when assessing data available for the baseline, current C stocks, and future monitoring.

Comparability – Methods should be similar among countries. International standards as outlined in IPCC guidelines and relevant sourcebooks should therefore be followed.

Completeness – Estimates should include—for the relevant geographical area—all relevant pools. When gaps exist, all relevant information and justification on these gaps should be documented in a transparent manner.

Accuracy – Estimates should be systematically neither over or under the true value, so far as can be judged, and uncertainties should be reduced so far as is practical. Appropriate methods should be used to promote accuracy in inventories and to quantify uncertainties in order to improve future inventories. The subprinciple of *conservativeness* is an important part of accuracy; it means that reductions in forest C emissions should, if anything, not be overestimated, or at least the risk of overestimation should be minimized.

For guidelines on reporting in a manner consistent with these principles, it is strongly recommended that Chapter 4 of GOFC-GOLD (2009) be read thoroughly and its suggestions followed, particularly the guidelines for reporting tables and inventory reports on pages 4-175 through 4-178.

Sampling rationale

Because not every tree or land parcel in a project area can be measured, sampling must be employed. Sampling is the process by which a subset of points or plots is studied in order to allow generalizations about the whole area of interest. Values attained from measuring a sample are an estimation of the equivalent value for the entire area. In order to evaluate how close the estimation is to reality, statistics are used (Pearson et al. 2005).

The two most relevant statistical concepts to know are accuracy and precision (Figure 2):

Accuracy is how close the sample measurements are to the true value. Good Practice Guidelines state that carbon estimates must strive for the highest accuracy possible, such that estimates are neither over- or underestimates (i.e., bias is avoided). For this reason, location of sample points must be effectively random within the study area.

Precision relates to the level of agreement among repeated measurements of a quantity. This is represented by how closely grouped the results are from various sampling points or plots. In other words, precision reflects the level of variation around the mean estimate. High precision (low uncertainty) is an objective of carbon assessments. Determining the number of sample points is a crucial step since precision usually increases with the number of sample points. Precision and uncertainty are treated in quantitative detail in later sections.

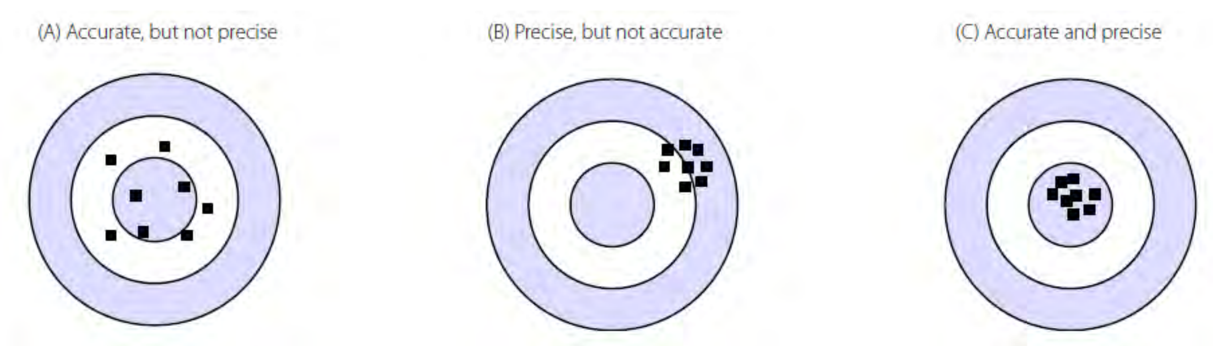


***Figure 2.** Bull's eye target example of accuracy and precision. From Pearson et al. (2005).*

Developing a Measurement Plan

The steps to preparing a robust measuring plan can be summarized as in Figure 3. Each of these steps should be done in a transparent, consistent, well-justified manner.

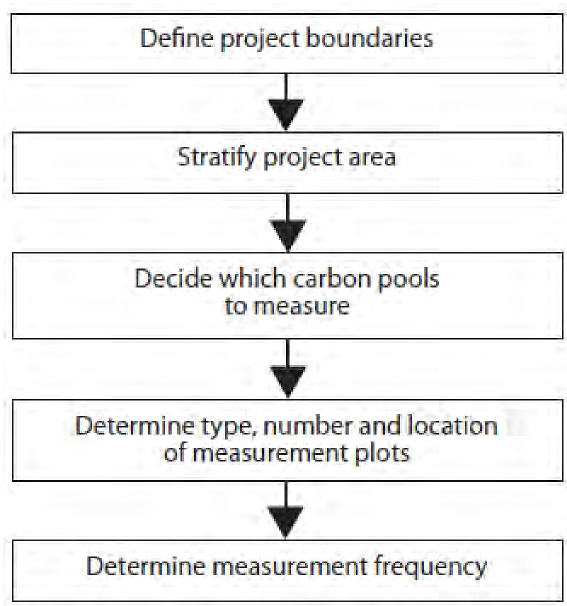


Figure 3. *Steps to preparing a measurement plan. From Pearson et al. (2005).*

1) <u>Define the Project Area Boundaries</u>

Spatial boundaries of the land under consideration need to be clearly defined and properly documented from the start to aid accurate measuring, accounting, and verification. Use GPS coordinates and/ or a map to achieve this. The specific requirements of this aspect may vary depending on the market mechanisms being sought. Some markets may only require a project-level carbon assessment for a specific land area as small as several hectares. Other markets, particularly emerging regulatory versions, may require national-level C assessments. In the latter case, a carbon assessment for SRF would be one component of a larger national effort.

For the Sundarbans Reserve Forest, the boundaries are well defined by legislation and only need to be clearly articulated and consistent over time. Note that aquatic portions of SRF—the rivers and sea channels—are not considered with respect to carbon storage under current regulations or markets. Carbon accounting and markets are currently focused on terrestrial carbon stores only, particularly forests. This means that, although the total area within SRF is ~600,000 hectares, only the ~412,000 hectares of actual land area are currently eligible for carbon accounting and carbon markets. This means that total carbon stocks in SRF need to be computed over the 412,000 hectares of land, not by the 600,000 hectares of total area.

2) Decide on Stratification of the Project Area

In some cases it may be desirable to stratify the project area into subpopulations, or 'strata,' that form relatively homogenous units. Because each stratum should have lower variation within it, fewer plots may be needed to achieve the same level of precision. Useful tools for defining strata include ground-truthed maps from satellite imagery, aerial photographs, and maps of vegetation, soils, or topography. Stratification could be based on, for example, land use or vegetation type, but should be carried out using criteria that are directly related to the variables to be measured—for example, the carbon pools in trees (e.g., only stratify based on differences in tree species dominance if those differences relate directly to biomass/carbon stocks).

For Sundarbans, it is recommended here that stratification not be employed, for several reasons. First, an existing systematic sampling grid is already in place, with historic data available from those ground points. This will allow past, current, and future data to be evaluated in a consistent manner. Second, as long as a systematic sampling grid was started from a random point (which the SRF inventory grid was), that sample layout is considered the most rigorous and intuitive. Third, Sundarbans is a dynamic region, with short- and long-term changes in forest cover and biomass occurring due to changes in hydrology, sedimentation, disease, and human factors. Thus, a stratification employed today may not make sense in the future as vegetation communities and lands shift spatially.

3) Decide Which Carbon Pools to Measure

Most international standards divide forests into roughly five carbon pools: 1) aboveground and belowground biomass of live trees, 2) non-tree vegetation, 3) dead wood, 4) forest floor (litter), and 5) soil. Not all pools are required to be measured in every project; decisions can be made at the project level to streamline the effort involved in carbon assessment. A pool should be measured if it is large, if it is likely to be affected by land use, or if the land-use effects or size of the pool are uncertain. Small pools or those unlikely to be affected by land use may be excluded.

Trees are always included since they are relatively easy to measure, good scaling equations exist, and they are heavily affected by land use. The importance of non-tree vegetation varies depending on ecosystem; it may be important where shrubs, leafy palms, or bamboo are a large biomass component. Dead wood is often an important pool in mature forests. Forest floor varies but may be an important pool in mature forests. Soil organic carbon is difficult to measure and may be slow to change with land use, but it should be considered because it can be a very large pool and one susceptible to land use. Mangroves such as Sundarbans, in particular, often have deep organic-rich soils resulting in large carbon pools; these are technically mineral soils rather than peat soils in most cases. Thus, either stock-change or gain-loss methods may be applied for soil C.

For the SRF carbon assessment, final decisions for which pools to measure should be made by project personnel with knowledge of the ecosystem. An initial recommendation here is to measure trees, non-tree vegetation, dead wood, and soil. Trees are the most susceptible to land use activities, and soil may be the largest and most uncertain carbon pool in mangroves. Dead wood and non-tree vegetation may be a significant biomass component in SRF and may change significantly with logging activities. Forest floor is usually a minor or even negligible biomass component in Asian-Pacific mangroves; if SRF is similar, this pool should be excluded here.

4) <u>Determine Type, Number, and Location of Measurement Plots</u>

Type— Permanent or Temporary:
Sourcebooks describe options for 'permanent' sample plots, in which all trees within plots are tagged and tracked through time, or 'temporary' sample plots, in which trees are not tagged. [Note that the latter plots are called 'temporary' even if they are permanently marked and revisited over time.] In the latter method, trees are treated like other C pools and are tracked at the plot level over time, rather than as individuals. Each method has its advantages and disadvantages (see sourcebooks for more detailed discussion), and the decision for approach is ultimately up to project personnel. For the time and logistical constraints imposed by mangrove field work, it is recommended here that trees are not tagged. Measurement and analysis guidelines in the remainder of this document follow this route.

Plot Shape:
The shape and size of sample plots is a trade-off between accuracy, precision, time, and cost for measurement. Plots can either be one fixed size or 'nested,' meaning that they contain smaller sub-units for various C pools. Nested plots are generally more practical and efficient in forests with a range of stem diameters and densities. The number of nests depends on the distribution of stem sizes in a given forest type. Plot nests can take the form of nested circles or rectangles (Figure 4). Circles have the advantage that the actual plot boundaries need not be measured, only the center point as long as reliable distance measuring equipment is available.

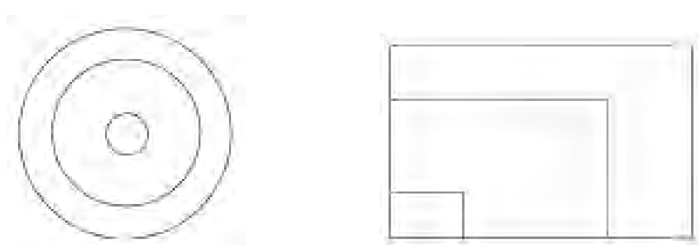


Figure 4. *Examples of circular and rectangular nested plots. Adapted from Pearson et al. (2005). High-frequency C pools (e.g. small trees) are measured in inner nests, while lower-frequency pools (e.g. large trees) are measured in outer large nests.*

Clustering:
Another consideration is whether, at a given plot, multiple sample units are clustered together, or if a single sample unit is employed. Many well established forest inventory programs, such as the United States' Forest Inventory and Analysis (FIA) program, use clustered sample units, commonly referred to as 'subplots.' Clustered plot designs tend to capture more microsite variation in vegetation, soils, etc., thereby reducing among-plot variation (increasing overall precision). Examples of clustered plot designs are shown in Figure 5.

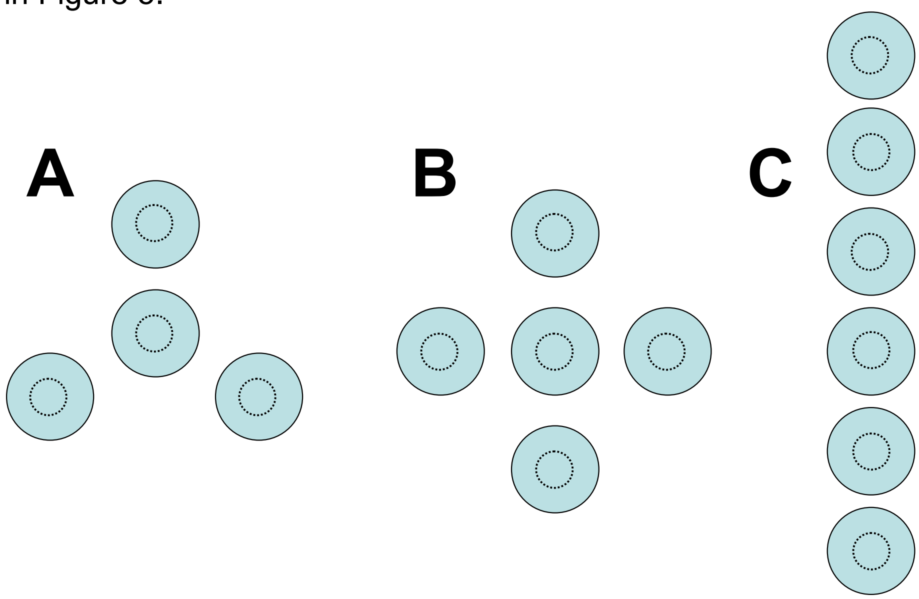


Figure 5. *Examples of clustered plot designs. The 'plot' is composed of a series of 'subplots' (blue circles). (**A**) and (**B**) are from the United States' Forest Inventory and Analysis (FIA), Forest Health Monitoring (FHM), and Current Vegetation Survey (CVS) programs (e.g., USDA 2008)—used for efficiently assessing larger ground areas and increasing overall precision. (**C**) is from the Indo-Pacific Forest C Study (Donato and Kauffman unpubl.)—used for assessing directional gradients, reducing species contagion, and increasing precision.*

For the SRF carbon assessment, a clustered plot composed of five circular subplots arranged as in option B in Figure 5 is recommended, thus taking advantage of the increased precision of clustered sampling, and the fact that this plot design was employed during the previous forest inventory for SRF. However a wide array of plot designs may be perfectly adequate depending on local knowledge and needs.

Number of plots:
It is important that sampling is carried out with statistical rigor. A key step is identifying the number of plots required to reach the desired precision level. An online tool for calculating the number of plots is available at: http://www.winrock.org/Ecosystems/tools.asp.

Typically the desired precision level is to target within 10% of the true value of the mean at the 95% confidence level. [95% confidence intervals are defined and treated quantitatively later in this document.] To estimate the number of plots required, some prior knowledge of the variation in carbon pools within the project area is needed—e.g., from a previous inventory if available, or from a preliminary sample of 6-10 plots. The variation in the tree pool captures most of the variation, so this can be used if that is the only available data (Pearson et al. 2007). Soil may be an exception, having its own variance that can be very large.

At the simplest level, the number of plots required should be calculated by:

Equation for number of sample plots

$$\text{Minimum number of sample plots } (n) = \left(\frac{t^*s}{E}\right)^2$$

n = the number of sample plots,
t = the sample statistic from the t-distribution for the 95% confidence interval; t usually is set at 2 as sample size is unknown at this stage,
s = standard deviation expected or known from previous/initial data,
E = allowable error or the desired half-width of the confidence interval. Calculated by multiplying the mean carbon stock by the desired precision, i.e., mean * 0.1 (for 10 percent precision)

Other, more complex equations are also available to estimate the minimum number of plots; see Pearson et al. (2007) for treatment of these options. Note that, if stratification of the project area is employed, the determination of number of plots must be conducted for each stratum.

The minimum sample size should be increased by about 10 percent to allow for plots that cannot be relocated or are lost due to unforeseen circumstances.

As an example, assuming the standard deviation is very high, perhaps 60% of the mean, or 180 Mg ha^{-1} (a conservative approach since it is likely not that high), the above equation can be solved with an objective of 10% precision:

$$\text{Minimum number of sample plots for Sundarbans } (n_{SRF}) = \left(\frac{2 * 180}{0.1 * 300}\right)^2$$

$$= 144 \text{ plots}$$

Example values are used only here, based on rough estimates and a conservative approach. This estimate may be refined based upon analysis of past inventory data.

Increasing this by 10 percent to allow for unforeseen circumstances yields an estimate of 158 plots. Thus, even if variation is very high, this number of plots should yield adequate precision for SRF.

Location:
Plot locations can be selected randomly or systematically (plot grid with random origin). Both approaches are defensible and tend to yield similar precision. However if some parts of the project area or strata have higher carbon content than others, systematic selection usually results in greater precision than random selection. Systematic sampling is also easily recognized as credible (Pearson et al. 2007).

Initial Recommendation for SRF:
The last SRF inventory, conducted in the 1990s, sampled approximately 1200 plots situated on a systematic grid at 1-minute intervals of latitude/longitude. Bangladesh FD personnel have communicated to the authors that this number of plots was impractical. Therefore, it is recommended here that the sampling grid be utilized, but using a systematic subsample. This approach should strike an acceptable balance between area coverage, precision, and practicality, while allowing past data to be leveraged. Moreover, the grid origin is an ecologically arbitrary point in lat/long space, so this grid can be considered a random, statistically rigorous sample.

Based on logistical constraints communicated by Bangladesh FD personnel, approximately 100-150 plots is the maximum number that can be sampled in a given census effort. This is still likely adequate for the C assessment (see above calculation) given local circumstances, and is similar to plot densities in difficult-access roadless areas that has been used by the United States' Forest Inventory and Analysis program. FD personnel have also expressed that ~300 plots may be needed to complete the forest resource inventory; this would be accomplished by either hiring additional crews or extending the census to a second dry season.

To facilitate these options, the original plot grid can be subsampled by selecting every second plot in both the x and y directions. This yields 295 plots (the full option). To attain a lower plot density, every second row of this new grid can be sampled; this yields 155 plots. Figure 6 and Table 2 illustrate these options, along with some smaller scale options. Thus, given limited resources, sampling can be conducted as a progression through the following options as resources allow (see Table 2):

- C assessment and inventory in one small pilot area.
- C assessment and inventory in one large pilot area.
- C assessment and inventory of entire SRF, 105 plots, all with soil samples.
- C assessment and inventory of entire SRF, 155 plots, all with soil samples.
- C assessment and inventory of entire SRF, 295 plots, half with soil samples.

Note that if the new subsample grid contains 'holes' where insufficient plots are located, plots could be added in a given area in a transparent, systematic manner.

Table 2. Options & resources needed for C assessment and forest inventory in SRF.

	1 small pilot study area	1 large pilot study area	SRF combined inventory, low density	SRF combined inventory, med. density	SRF combined inventory, high density (soil in only ½ of plots)
# plots	12	30	105	155	295
# plots in which soil is sampled	12	30	105	155	155
# soil samples to be analyzed	24	60	210	310	310
time needed	1 month	1 - 2 months	4 months	4 - 5 months	4 - 5 months
# crews	1	1 – 2	2	2 - 3	4
# crew members (not incl. guards)	6	6 – 12	12	12 - 18	24

5) Determine Measurement Frequency

Frequency of monitoring is a cost-benefit analysis and should be determined by the magnitude of expected change in carbon pools. Thus, the carbon dynamics of land use activities and measurement costs should be considered. Given the dynamics of forest processes, they generally are measured at intervals of 5 years (Pearson et al. 2005, 2007). For carbon pools that respond more slowly, e.g., soil, even longer periods can be used – perhaps 10 or even 20 years between censuses (sampling events). Note that a disadvantage of long periods between censuses is the risk of natural or anthropogenic disturbance, the effects of which may by missed with widely spaced monitoring intervals (Pearson et al. 2007). Also, in some cases, it may not be possible to claim market credits for pools not measured with at least a 5-year frequency (Pearson et al. 2005).

To determine that plots are representative of the entire project area, periodic checks should be made to ensure that the overall activity is performing in the same way as the plots. Field indicators of carbon stock changes or high-resolution satellite imagery can be used to accomplish this task (Pearson et al. 2007).

For SRF, 5-year monitoring intervals for aboveground C pools, with soil sampling every other census (i.e., every 10 years) may be sufficient.

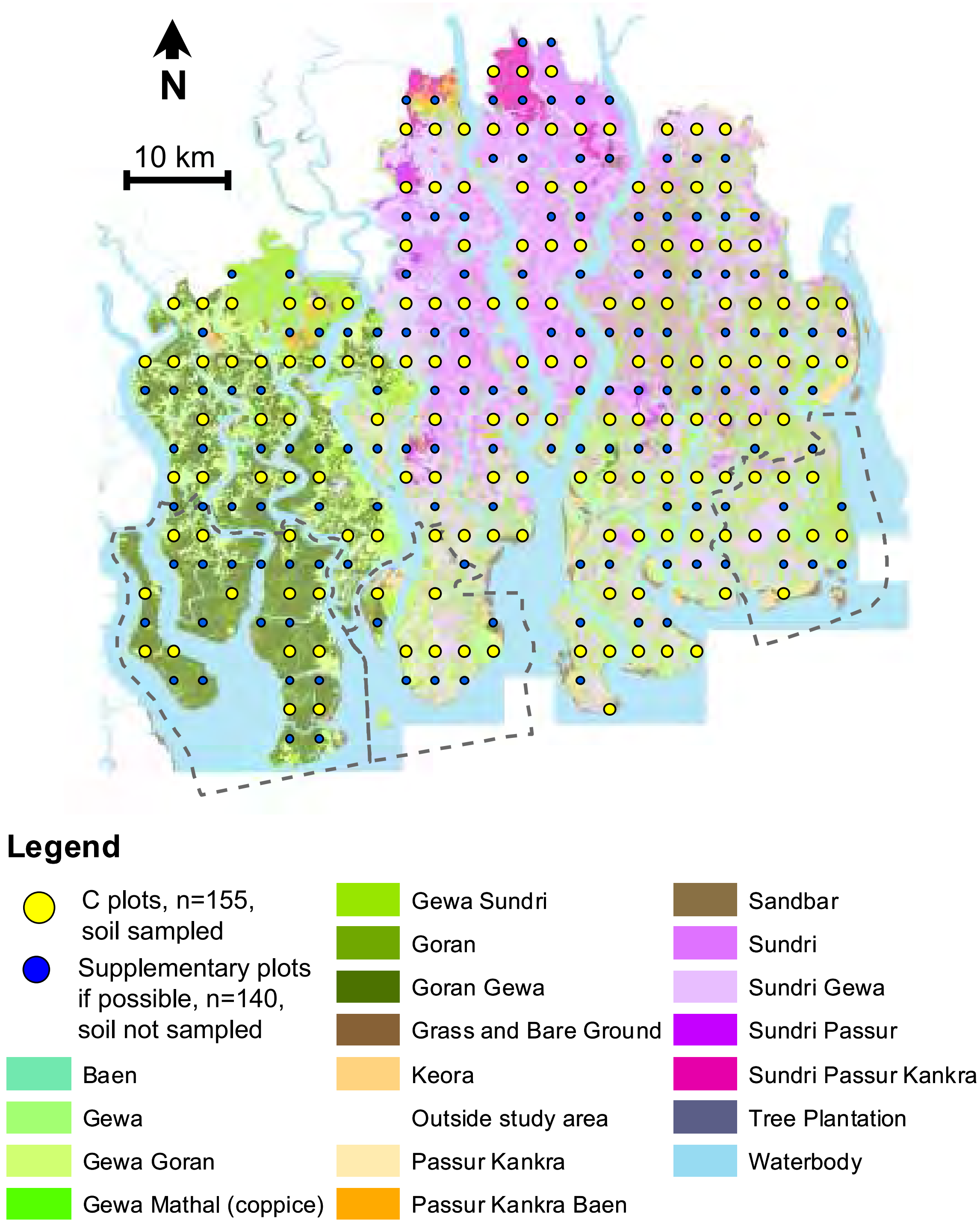


Figure 6. *Proposed sampling scheme for Sundarbans carbon and forest inventory. A systematic grid is employed, with 295 plots spaced at regular intervals of latitude/longitude. Gaps in the grid are due to watercourses. These plots are a systematic subsample of an existing inventory grid of ~1200 plots that were measured in the 1990s, thus enabling past inventory data to be utilized for baseline comparisons.*

FIELD PROCEDURES

Unique considerations for measuring C in mangroves

Tides

Most mangroves are subject to semi-diurnal tidal cycles. Sampling of certain carbon pools, primarily the soil and surface materials, are only practical when the soil surface is exposed to the air. Thus, most stands must be sampled when the tide is low.

The "Rule of Twelfths" provides insight into the length of time available to sample. The change in water level during the tide changes in a predictably nonlinear pattern:

- During first hour after high water the water drops **1/12**th of the full range.
- During the second hour an additional **2/12**th.
- During the third hour an additional **3/12**th.
- During the fourth hour an additional **3/12**th.
- During the fifth hour an additional **2/12**th.
- During the sixth hour an additional **1/12**th.
- This pattern repeats as the tide rises again.

The sampling window generally last about 4 hours, in the time span bracketing the low tide (Figure 7). This short window necessitates an efficient sampling protocol.

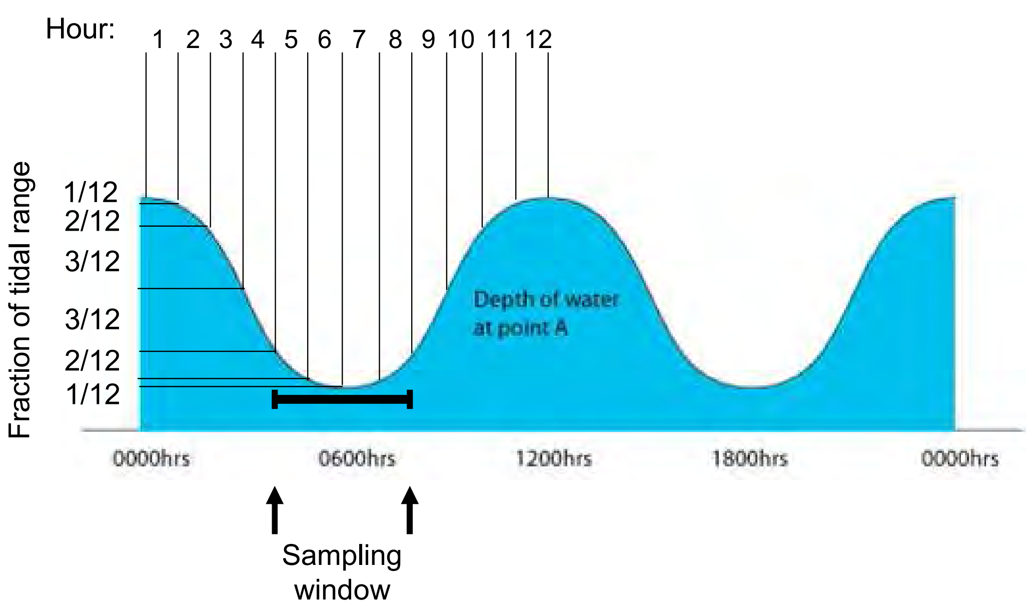


Figure 7. *Tides and the "Rule of Twelfths." A period of minimal change in water level occurs for ~2 hours on either side of low tide, creating a 4-hour sampling window.*

Plot Establishment and Layout

The plots are situated in a systematic grid across the Sundarbans Reserve Forest, at regular intervals of latitude and longitude (Figure 6). There are some gaps in the proposed sampling grid; these are a carry-over from the previous inventory and largely reflect where large water channels preclude forest measurements. If a grid point was not measured in previous inventory (gap in grid), it should not be measured now. Upon arriving at a mapped point, if it is in an open water channel for more than 200 m in every direction, do not establish a plot. If there is land within any part of the plot (i.e., any subplot), do measure the plot. Record the percentage of each subplot occupied by water canals on the understory/canopy cover datasheet.

Plot Layout

The plot consists of 5 circular subplots, oriented as a center subplot with four more subplots oriented in cardinal directions from the center (east, west, south, north) (Figure 8). Different forest components are measured in different size circles ('nests'), co-located at the center of each subplot.

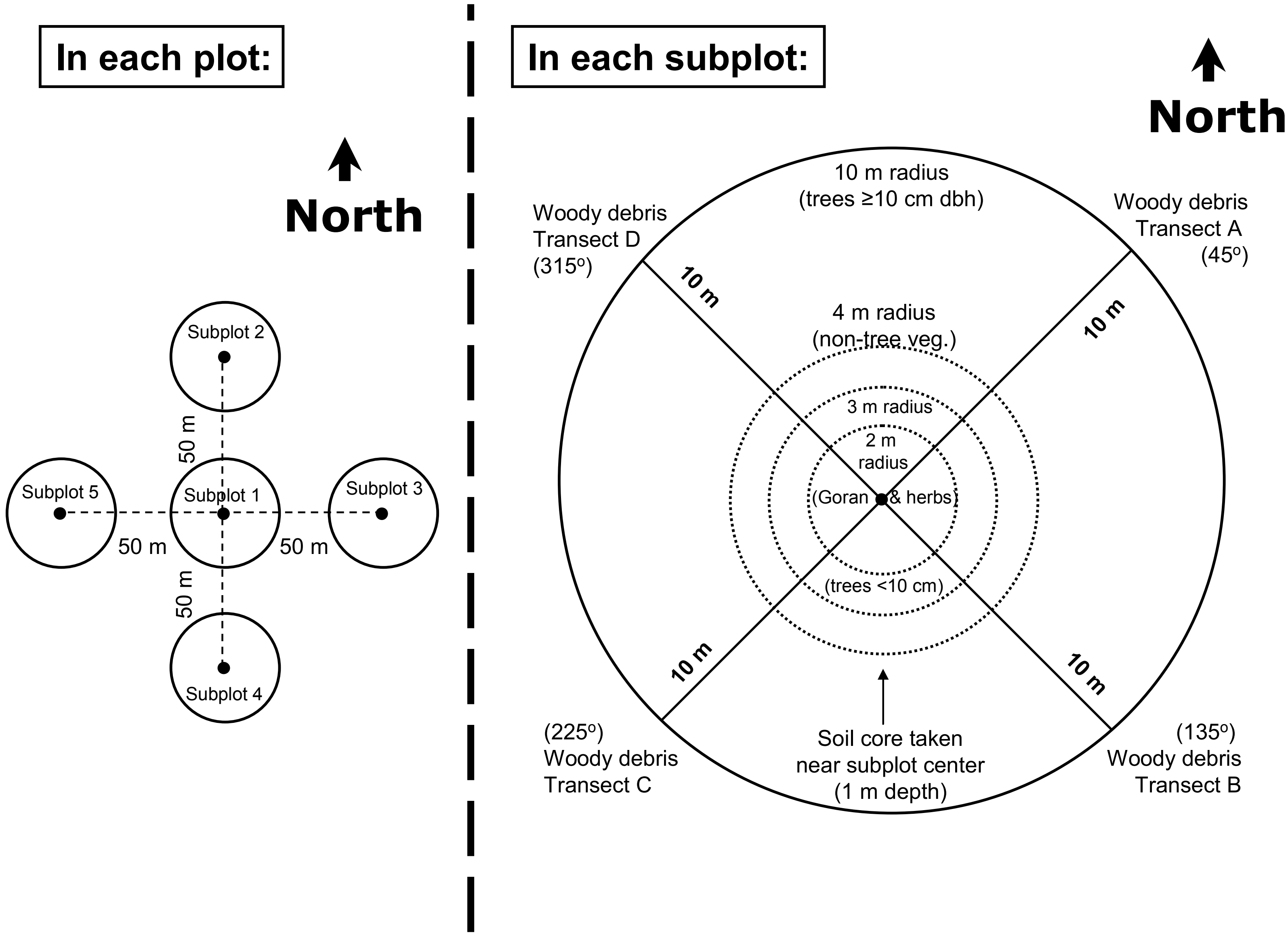


Figure 8. *Schematic of plot layout.*

General information at each plot

At the start point of each plot (subplot 1 center), record the following information on the general plot datasheet:

- Plot number
- Date
- Crew members present
- Range, Compartment, and Block number
- GPS coordinates in latitude/longitude (dd.ddddd°), and precision (± X m)
    - Mark a waypoint in the GPS; file name is the plot number.
    - Make sure the appropriate datum is used (e.g., India-Bangladesh or WGS84, depending on what is normally used in SRF).
- Notes on directions to plot (include waypoints of access points/boat mooring if applicable)

The following information should be recorded by circling the appropriate choice on the data form.

- Site category: Forest, Scrub (<5 m height), Grass/Bare Ground, or Other (if other, describe)
- Forest condition: Intact, Degraded, or Deforested (see above definitions)
- Topography (microrelief): Flat, Depression, Levee, Slope (if sloped, record %)
- Soil description: Loose Sand, Hard Clay, Soft Mud, or Fluid Mud
- Disturbance evidence:
    - Cyclone damage: Not Evident, Light, Moderate, or Severe
    - Sundri top-dying: Not Evident, 0-30% (trees affected), 30-70%, or 70-100%
    - Timber harvest: Not Evident, Low (<30% basal area), Medium (30-70%), or High (>70%). Also describe the harvest.
    - Other disease/disturbance: Not Evident, Light, Moderate, or Severe. Also describe the other disease/disturbance.

The bottom of every data sheet provides room to document quality control activities. At the end of every field outing, all data sheets should be reviewed by the recorder for completeness, legibility, and accuracy. Once satisfied by the quality of data recorded, the recorder (or other data reviewer) should write their name and the date of the review, along with any notes on issues that were noticed during the check so that they can be prevented in the future. Similarly, when data is entered into a computer program, such as Microsoft Excel[1], each

[1] The use of trade, firm, or corporation names in this document is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or Forest Service of any product or service to the exclusion of others that may be suitable.

data sheet should be compared to what was entered into the computer to ensure accuracy in data entry. Once the person entering data has compared the computer entry to the data sheet and fixed any errors, they should write their name at the bottom of the data sheet and the date of data entry. Any issues should be noted so that they can be corrected in the future. In addition, a sub-sample of the data sheets should be compared to the computer entry by someone other than the person who entered the data (minimum 10%, the exact number is dependent on the QA/QC plan and the amount of errors found—more errors warrant more data reviews). The data reviewer should also write their name and the date of the data review, along with any notes on issues that were apparent or corrections that were made. It is important that all issues that are noted on the data sheets are brought to the attention of the field supervisor so that preventative measures can be taken.

Plot Photos

From plot center (subplot 1 only), take 4 digital photographs—one in each cardinal direction (N, S, E, W). In each photo, hold a small sign with the plot number, photo direction, and date in the lower corner of the frame. Use the back of a datasheet and a permanent marker to make the sign. Make sure most of the photo is of the forest, not the sign or the ground. Once photos are downloaded onto a computer, the photo names should be changed to "plotnumber_direction_2009-10" (e.g., 738_N_2009-10). Once the photo names have been changed, their new names should be recorded on the datasheet, with the storage location. Photos should be stored electronically with other project data in a photos folder with separate plot folders.

Measurements in subplots

Tree Survey

Trees dominate the aboveground carbon pool and are the best indicator of land-use change. It is essential to measure trees thoroughly and accurately. The basic concept is that measurements of stem diameter are used in allometric equations to compute biomass and carbon stocks.

What counts as a tree

- **All live woody stems having a diameter at breast height of 10 cm or greater. Diameter at breast height (dbh) is the stem diameter 1.3 m above the ground.**
- **Any dead woody stem (snag or stump) with diameter ≥ 10 cm, provided its angle from true vertical is less than 45^{o} (Figure 9).**

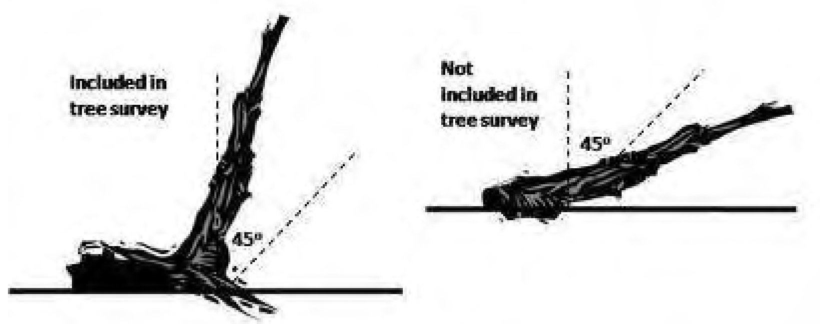


Figure 9. *If a dead tree leans more than 45^{o} from vertical, it is not included in the tree survey.*

The subplot

- **Subplot is a circle with radius 10 m. To check if trees are in the subplot, use the laser rangefinder, the linear side of a 10-m diameter tape, or the woody debris transect tapes.**
- A tree is included in the survey if at least 50% of the stem is inside the subplot perimeter. Alternately include and exclude individuals too close to call.
- Take care to measure every tree once and only once.

Measurements

- For each tree, record species and dbh using a diameter-tape (to nearest 0.1 cm)
- If the tree is dead, record “y” in the dead column of the datasheet. Record other data as normal. If species is unknown, record “unk” in species column. Record dead trees’ decay status as follows (see Figure 10):
    - <u>Status 1</u>: Retains small branches and twigs; resembles a live tree except for absence of leaves
    - <u>Status 2</u>: No twigs/small branches; may have large branches or stem only
        - For status 2 dead trees, also record diameter at base of tree, and total tree height using laser tool or clinometer.
        - Record whether status 2 dead trees were cut in the remarks column.
        - Stumps (status 2 dead trees not reaching dbh, cut or natural) are recorded in this survey, provided they have a top diameter ≥ 10 cm—i.e., they would be large enough for the tree survey if not cut/broken. If a stump does not reach breast height, only record base diam. & ht.

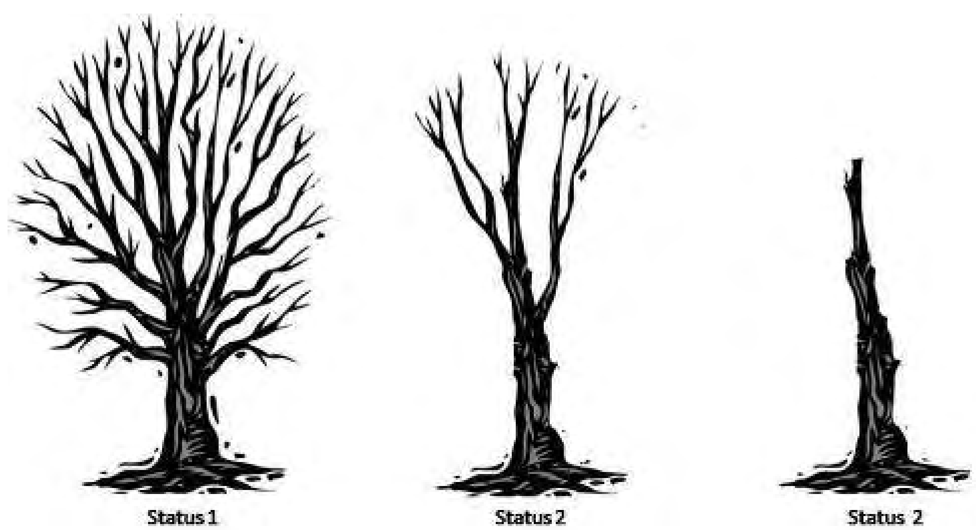


Figure 10. *Examples of dead tree decay status. Class 1 trees retain twigs and small branches. Class 2 is a broad category including trees with no twigs or small branches; these may have large branches, or stem only. Adapted from Walker et al. (unpubl.).*

- If the tree is a Sundri and top-dying is present, record whether greater or less than 50% of the crown is affected.

- Height of 3 co-dominant trees: For the 3 co-dominant trees closest to each subplot center, measure tree height to nearest 0.1 m using the laser tool or clinometer.
    - A co-dominant tree is one forming the main overstory layer, receiving sunlight on top of crown only. It is not emergent above the main layer, nor is it completely shaded below (Figure 11).

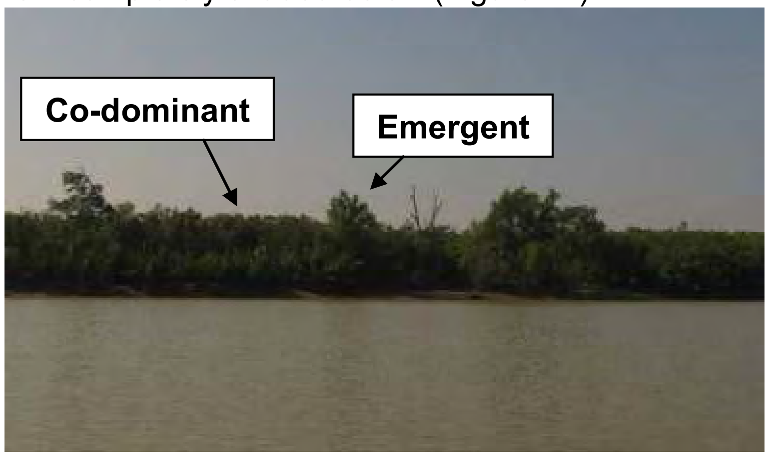


Figure 11. *Example of co-dominant versus emergent (dominant) canopy position.*

Notes:

- Be sure to use the diameter side of the dbh tape, not the linear side.
- If there is any slope, measure dbh as 1.3 m from the uphill side of the tree.
- Trees are considered alive if any green leaves are present.
- For trees that fork into multiple stems at or below dbh, measure below the fork. If impossible to measure below, then measure as multiple trees. (Although traditional forestry dictates that forked stems be measured as separate trees, for biomass computations it is more accurate to measure as one tree.)
- For leaning trees, wrap dbh tape perpendicular to stem, not parallel to ground.
- Measure lianas just as trees, but record dbh only and “liana” for species. Take care that the same liana is not measured more than once.
- Palms with woody trunks are measured in the tree survey. No dbh measurement is required, only height. Species is recorded if known; otherwise “palm.” Note that all palms reaching dbh height are recorded in the tree circle, even if their dbh is less than 5 cm.
- For trees with buttresses/prop-roots above 1.3 m, measure the dbh 0.5 m above the highest buttress/prop-root (see, e.g., Komiyama et al. 2005).
- If laser rangefinder is unavailable, use a clinometer to measure tree heights (to nearest 1 m). In this case, in the height column record percent slope to top and bottom of tree, and the distance the clinometer was from the tree.

- Note that, if desired, trees can also be tagged using aluminium tree tags and nails. This leads to a much different approach to tracking changes in tree carbon over time (‘permanent’ plots). Because of sampling constraints when working in mangroves, it is recommended here that tree tagging is not employed for this assessment. If desired for this or future surveys, or for other forest inventory purposes, see Pearson et al. (2005) and Pearson et al. (2007) for how to conduct C monitoring calculations using tagged trees.

Sapling and Seedling Survey

What counts as a sapling

- **All live trees reaching breast height (1.3 m), but having a dbh < 10 cm.**
- Any dead tree having dbh < 10 cm, provided its angle from true vertical is less than 45^o.

What counts as a seedling

- **All live trees not reaching breast height (1.3 m).**
- Any dead tree not reaching breast height and having a top diameter < 10 cm, provided its angle from true vertical is less than 45^o.

The subplot

- **Subplot is a circle with radius 2 m (concentric with tree survey circle).**
- Saplings and seedlings are included in the survey if at least 50% of the stem is inside the subplot perimeter. Alternately include and exclude individuals too close to call.
- Take care to measure every individual once and only once.

Measurements

- For each sapling, record the tree species and dbh (to the nearest 0.1 cm), using a caliper or diameter tape.
- If the sapling is dead, record “y” in the dead column.
- Live seedlings are recorded as a simple count of individuals. Record dominant seedling species.
- Dead seedlings are recorded as a count. Include small stumps (< 5 cm diameter and not reaching breast height) in this count.

Notes:

- Notes from the tree survey apply to the seedling/sapling survey.
- Palms with woody trunks, but not reaching breast height (<1.3 m height), are counted in the seedling tally.
- For woody shrubs with vertically oriented stems (e.g., *Hibiscus*), measure their individual stems as saplings if they reach breast height, and seedlings if they do not. One shrub individual may therefore contain many sapling stems and many seedling stems.

Canopy cover

Canopy cover measurements may aid in leveraging remotely sensed data to track forest degradation.

A spherical densiometer is used to estimate canopy cover. It should be held 30-40 cm in front of your body and at elbow height, so that your head is not visible in the mirror. Level the instrument using the level bubble. In each square of the grid, imagine that there are four dots, representing the center of quarter-square subdivisions of each of the squares (Figure 12). Systematically count the number of dots NOT occupied by canopy (where you can see sky at that dot). Record this number on the datasheet. Make four readings per location – facing north, south, east, and west.

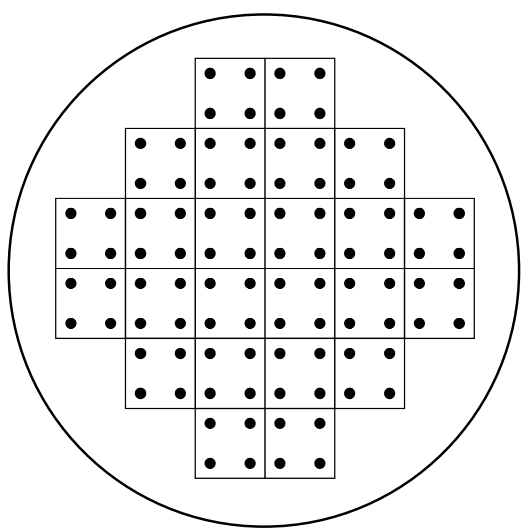


Figure 12. Schematic of densiometer mirror, with the 4 dots depicted in each square. Count the number of dots NOT occupied by the canopy, in the 4 cardinal directions at each subplot.

Water Canal Cover

For each subplot, record the percent of the subplot area occupied by water canals that are void of vegetation. Also record an ocular estimate of the canal width to the nearest meter.

Non-Tree Vegetation Survey

Non-woody palms (e.g., *Nypa fruticans*), goran (*Ceriops*), and herbaceous vegetation should be measured in the inner nested subplots. Options for these include destructive harvests in each sample plot or non-destructive sampling using allometric relationships. Non-destructive sampling is preferred for the efficiency required of mangrove plots; this employs a one-time destructive harvest to construct the appropriate allometries (see relevant section below).

What counts as non-tree vegetation

- Any vegetation not meeting the requirements of the tree or sapling/seedling survey.

The subplot

- Non-woody palms, ferns, etc. are measured in a circle with radius 4 m (concentric with tree survey circle).
- Goran and herbaceous vegetation (grasses and herbs) are measured in a 2-m radius inner circle.

Measurements, 4-m radius circle

- *Non-woody palms* (e.g., *Nypa*): count the number of stems rooted in the subplot (not individuals or clumps, but separate stems).
- *Pandanus*: Record the number of clumps (bunches of leaves) in the subplot.
- *Tiger fern*: Record the number of clumps (bunches of stems) in the subplot.
- *Woody shrubs*: Measure their individual stems as part of the sapling/seedling survey (see sapling/seedling survey notes, above).
- *Other*: When other vegetation is encountered, field personnel will need to make decisions on reasonably efficient and accurate methods for biomass estimation.

Measurements, 2-m radius circle

- <u>*Goran*</u> is simply tallied (counted) by the number of stems in each of 4 size classes. The size classes are the same as those for woody debris (0-0.6 cm, 0.6-2.5 cm, 2.5-7.6 cm, >7.6 cm). The diameter is measured at the base, above the collar. For branching stems, record the lower 'parent' stem diameter, not each branch. No distinction is necessary between live and dead stems (however make a note if >25% of stems in subplot are dead).
- <u>*Herbaceous vegetation*</u>: Visually estimate and record percent ground cover of herbs and grasses separately. Record to the nearest 1% if below 10, and to the nearest 5% if between 10-100%.

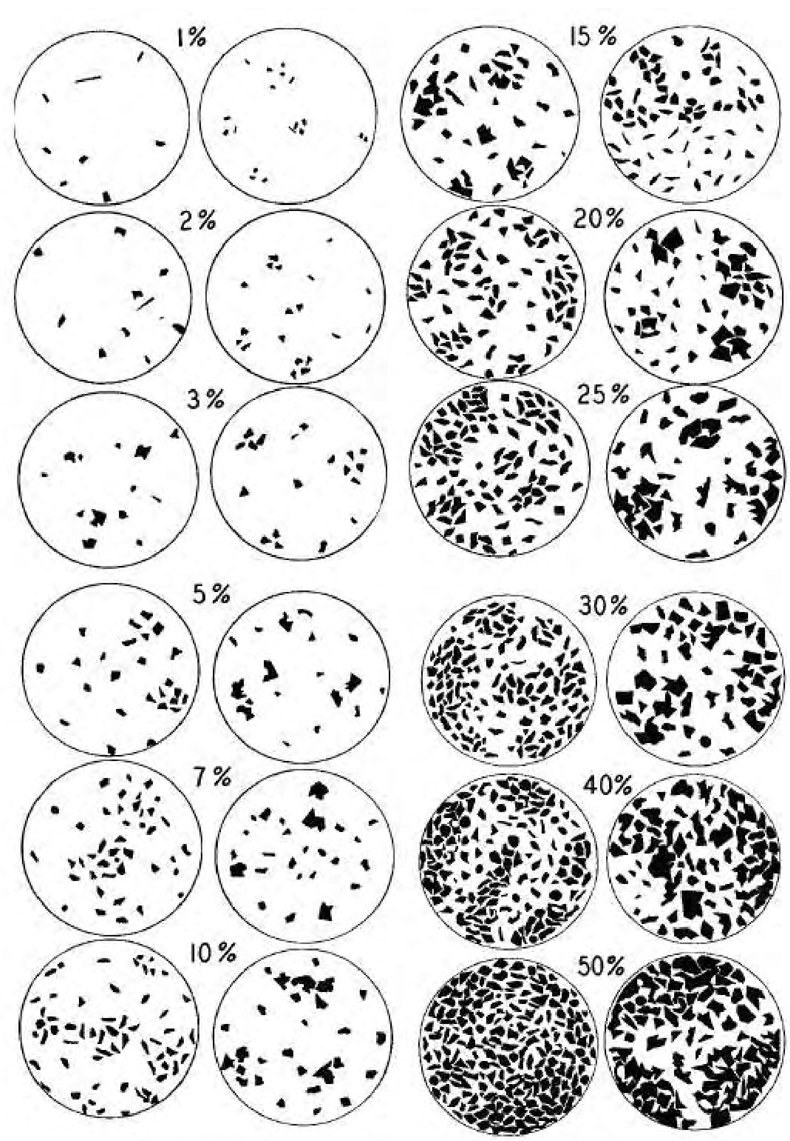


***Figure 13.** Reference scatterplots for estimating percent cover. From Terry and Chillingar (1955) as cited in USDA (2008).*

Forest Floor (Litter)

- The forest floor is defined as all dead organic surface material on top of the mineral soil. In mangroves, the amount (and therefore carbon stock) of this material is usually negligible due to the effects of tides, seasonal river flooding, and the activities of fauna such as detritus-consuming crabs. Therefore, in accordance with sourcebook recommendations, we recommend not measuring this pool.

- However, litter sampling is briefly described below in the event that project personnel decide that it is a significant carbon pool.
    - To the extent possible, sample litter at the same time of year at each census to avoid any seasonal effects.
    - Using the folding ruler, lay a 30 cm x 30 cm square sampling frame down on the soil surface, located on the outer edge of the 4-m radius subplot. Collect all organic surface material, excluding woody particles, which are already measured in a separate survey. Use a blade to cut litter pieces that fall on the border of the frame.
    - Collect the material in a sturdy bag or container, clearly labeled with "SRF C project", date, plot, and subplot. Oven-dry to constant mass, and record the final dry mass (minus bag or container mass).
    - If sample bulk is excessive, record the fresh (wet) mass in the field, then take a well-mixed representative subsample of manageable size (~80-100 g). Discard the remainder. Record the wet mass of the subsample, dry to constant mass, and use the ratio between the subsample's wet and dry mass to estimate the dry mass of the total sample.

Woody Debris Survey

- Woody debris (down, dead wood material) can be a significant component of aboveground biomass and may be affected by land use change.

- The planar intersect technique involves counting intersections of woody pieces with a vertical sampling plane (transect).

- A survey tape is run out from subplot center for 10 meters in each of 4 directions, oriented at 45-degree angles from the main transect line. Use a compass to run the transect tape on a straight line.
    - transect A: 45°
    - transect B: 135°
    - transect C: 225°
    - transect D: 315°

- Woody debris intersecting the transect plane is recorded, up to a height of 2 meters above the forest floor.

Figure 14. *Example of a woody debris transect tape in a mangrove (left), and using the down-wood gauge to classify pieces by size (right). The upper right piece is a medium class; the lower right piece is small class.*

- The slope of the actual survey tape can be different from slope of the overall plot. For example, a transect laid out diagonally down and across a slope will have a gentler slope than the actual hillside. A perfectly sidehilling tape would have a slope of zero. Most mangrove transects have negligible slope, but when there is a slope, record the % slope of the actual survey tape in the "transect" column under the letter.

- Woody debris is categorized into 4 size classes: Small, Medium, Large, and Extra-Large. These size classes are regularly used in forest inventories, and convenient measurement tools exist to streamline field sampling based on these cutoffs. Use the aluminium down-wood gauge to determine the size class of each piece encountered.

    - Size classes are:

Small	0 – 0.6 cm
Medium	0.6 – 2.5 cm

Large	2.5 – 7.6 cm
Extra-Large	≥ 7.6 cm

- Small, medium, and large pieces are tallied as the number of pieces that cross the transect tape. They are tallied separately for each size class. No diameter measurement is needed.
- Extra-large pieces require more data to be taken. For each piece crossing the transect, record its true diameter at line intercept using a ruler. Also record the decay status: sound (machete bounces off or only sinks slightly when struck) or rotten (machete sinks deeply and wood is crumbly with significant loss).
- Small and medium pieces can be very abundant, so to save time they are only sampled along sub-sections of each transect. These sub-sections start from the distal end of the transect (meter 10). Small pieces are only tallied for 2 meters of transect (from meter 10 to meter 8). Medium pieces are only tallied for 5 meters of transect (from meter 10 to meter 5). Large and extra-large pieces are recorded along all 10 meters. See Figure 15.

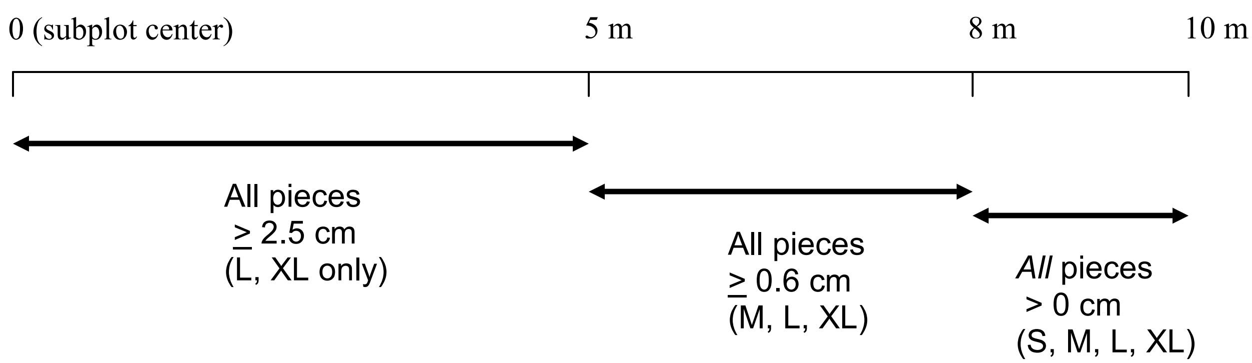


Figure 15. *Schematic of wood debris transect*

- What counts as woody debris?
  - Any downed, dead woody material (twigs, branches, or stems of trees and shrubs) that has fallen and lies within 2 m of the ground. Dead trees that lean at an angle of > 45^o from true vertical also count.
  - The transect tape must intersect the central axis of the piece for it to be counted. This means that if the tape only clips a corner at the end of a log, it does not count.
  - Any piece can be recorded multiple times if the tape intersects it more than once (e.g., a curved piece, or at both the branch and the stem of a fallen tree).
  - Count wood slivers, bark and irregular chunks; visually mold these pieces into cylinders for determining size class.

- Count *uprooted* stumps and roots not encased in soil. Do not count undisturbed stumps or roots still in contact with soil.
- The piece must be in or above the litter layer to count; it does not count if its central axis is buried in soil at the point of intersection.
- Dead branches and stems still attached to standing trees or shrubs do not count.

Soil Sampling

- To accurately quantify the soil carbon pool, three parameters must be evaluated: 1) soil depth, 2) soil bulk density (BD; mass per volume), and 3) organic carbon concentration (%OC).

- Notes on adaptation of common guidelines:

  - *Soil Depth*: For many C assessments, sampling is generally to a fixed depth of 30 cm, since most soil C is in the top horizons and this is the most vulnerable to land-use change. However, mangroves and peat swamps often have deep organic-rich soils with little vertical differentiation (see, e.g., IRDP of Sundarbans RF, vol. 1), and land-use may have effects on deeper layers due to drainage, oxidation, etc. Therefore, it is recommended that the top 100 cm are sampled for this assessment. The soil profile should be sampled from 0-30 cm depth, plus an additional sample representing the 30-100 cm depth range.

- Measuring soil depth: A 'bottom' of the soil profile is unlikely to be reached in the deep sediments of Sundarbans, so measuring soil depth is not necessary. [In mangroves over coral sands or bedrock, or in peat swamps, measuring soil depth with a probe such as a bamboo pole is important.]

- Obtaining soil samples for bulk density and %OC: A core sample is taken near the center of each subplot with a 1-m long open-faced peat auger. The goal is to obtain a sample as undisturbed as possible. Move 1 meter from subplot center in a random direction. Remove any organic litter from the surface of the sample point. Then steadily insert the auger vertically into the soil until the top of the sampler is level with the soil surface. If the auger will not penetrate to full depth, do not force it, as this may be a large root; instead try another location. Once at depth, twist the auger in a clockwise direction a few times to cut through any remaining fine roots. Gently pull auger out of soil. If an undisturbed sample has not been obtained, clean the auger out and try another location.

  - Once an undisturbed soil core is extracted, use a serrated knife to gently cut and remove the soil from the auger face, to obtain a smooth surface on the core, level with the auger edges. Work around coarse roots if necessary.

- Use a ruler and blade to mark the 30-cm depth line. From the mid-point of the 0-30 cm interval, take a 5-cm long sample from the soil core, using the ruler and blade. Avoid coarse roots (>2 mm diameter). The exact location of the sample may need to be varied to avoid coarse roots.

- Place sample in a numbered soil container; take care to avoid any loss of sample. Record container number. This sample will be used to determine %OC.

- Take another 5-cm long sample, immediately adjacent to the previous sample that was removed from the core; place in another numbered container. Record container #. This sample will be used for bulk density determination.

- Repeat this process for the 30-100 cm interval of the core, taking two 5-cm samples from the midpoint (~65 cm depth).

- If soil is especially dense/hard, it may be necessary to first obtain the 0-30 cm sample, then re-insert the auger into the hole to obtain a deeper sample.

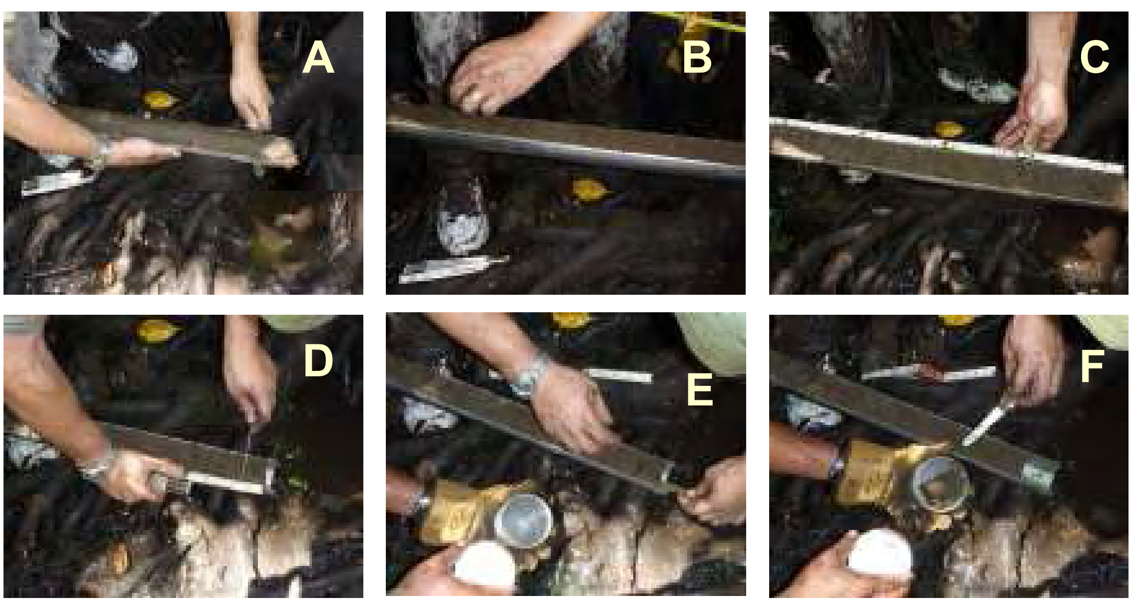


Figure 16. *Collection of soil samples from open-face auger. A: Cutting the soil away from auger face. B: Cleaned, flat surface of soil core. C: Measuring and marking the depth intervals. D: Cutting a sample. E: Removal of sample from auger. F: Collection of sample in numbered container.*

- <u>If open-face auger will not work</u>: The open-face auger is designed for mucky soils with high organic content. Sometimes it will not work, for example if the soil is not well consolidated (e.g., sand). In this case, use the slide hammer and dutch auger to obtain samples. If this decision is made, it must be done consistently across all 5 subplots within a plot. NOTE: Always record on datasheet which tool was used.

    - Clear away the surface litter.

    - Insert sampling sleeve(s) into slide hammer's aluminium bit; screw bit onto slide hammer.

    - Insert bit into the soil and use the hammering mechanism to get to depth. Only go down until the top of the bit is flush with the surface. Going deeper will compact the soil, resulting in over-estimation of bulk density.

    - Retrieve the bit from the soil, unscrew bit from hammer, and extract sampling sleeve. Cut sample so it is flush with the open ends of the sleeve.

    - Push soil out of sleeve and into a numbered collection container. Record the container number.

    - If possible, use the second sleeve within the bit to obtain a second sample from that depth interval (for nutrient sample). If not possible, a second hole will need to be sampled (see last step below).

    - Using the dutch auger, bore into the original soil hole to a depth of ~60 cm (a mark on the auger rod may help). Clear the hole to the extent possible.

    - Re-insert the slide hammer (with aluminium bit and sample sleeve re-assembled) into this deeper hole until the bottom is felt.

    - Hammer down approximately 10 cm. Again, do not go too deep.

    - Repeat the sample extraction and collection process for the 30 – 100 m sample as for the surface sample.

    - If necessary, repeat entire process for the nutrient sample.

- <u>Pre-laboratory processing of soil samples</u>: Samples must be dried as much as possible before storage and transport to the laboratory.

  In the field:

- Air-dry the samples by opening the containers, keeping the numbered lid with the container (on underside), and place in the sun during the day. Re-close the containers at night to avoid dew condensation. Repeat over multiple days.

- When the samples are dried, combine the five %OC samples from the 0-30 cm depth interval for each plot into one plastic whirl-pak (or two if necessary). Have the whirl-pak(s) pre-labeled with “SRF C project”, “Nutrients”, date, plot, and depth interval. Repeat for the 30-100 cm depth interval.

- Repeat the above step for the bulk density samples from each plot (whirl-pak labels should read “SRF C project”, “Bulk Density”, date, plot, and depth interval).

- Take the samples to the drying oven facility as soon as possible.

Oven-drying

- Remove the soil samples from the whirl-paks; save the labeled whirl-paks for future use.

- Keep the combined samples together (5 from each plot for 0-30 cm interval stay together, and 5 from each plot for 30-100 cm interval stay together). Place combined samples in oven-safe containers. Aluminium foil can be used to form containers if needed. Keep careful track of which samples are from which plots; label the oven containers as needed. (Note: the plastic field containers are only rated to 100 °C maximum; never put those containers in an oven above that temperature.)

- Bulk density samples should be dried to constant mass in oven-safe containers at 105 °C.

- Nutrient samples should be dried to constant mass *in a separate oven* at 50 °C. The temperature is lower because higher temperatures may reduce the carbon in the sample.

- *Drying to constant mass*: Dry samples for at least 48 hours, then check samples for dryness. Samples that are dry to look and feel should be weighed (with container) on a digital scale; record the value on the soil datasheet. Take care to avoid any loss of sample. Return samples to oven, let dry for at least another 12-24 hours, then re-weigh, recording the mass on the datasheet. Keep checking and re-weighing at 12-24 hour intervals until the mass does not change from previous weighing, indicating that no more water has left the sample. Record and circle the last dry mass value.

- *Bulk density samples:* Once samples have been completely dried and weighed, wipe any residual soil dust out of containers with a clean rag. Weigh the empty containers with and record this mass on the datasheet. Once the data are entered electronically and backed up, these samples can be archived for future reference or discarded.

- *Nutrient samples*: Once the samples have been completely dried and weighed, return the samples to the appropriate labeled whirl-paks and send to the laboratory for analysis.

Equipment maintenance

Mangroves are extremely harsh on equipment. Corrosion is a major factor due to exposure to salty water and soil, and can happen within hours. Strive to rinse all equipment with fresh water after every day in the field. This is especially important for steel equipment with screw-on threads; these <u>must</u> be unscrewed and rinsed every day. Also, take care to protect the screw-on threads during equipment transport.

When equipment will not be used for an extended period (more than ~3 days), coat the metal parts with a light oil as a protectant.

Mark all equipment with permanent marker—project name, organization, etc.—so that it remains with the inventory project.

<u>Destructive harvests for allometries and wood densities</u>

For some forest components, region-specific allometric equations may not yet exist. For these components, a one-time destructive harvest will be needed to scale plot measurements to biomass and carbon. These components include shrubs, ferns, non-woody palms, seedlings, and possibly others. Decisions can be made by field personnel to add new allometries as the data require.

<u>Non-woody palms</u>:

- These are palms such as *Nypa fruticans* and similarly built species, which only have large leaves aboveground. Because these are only recorded by count in the plots, a mean biomass must be used to scale to carbon pool.
- Select 25-30 palm fronds from different individuals, outside of any sample plot. Include all common species in this sample.
- Cut frond at ground level and weigh it; record on datasheet.
- Take a manageable subsample from each frond and weigh. Record on datasheet. Clearly label with frond number.

- Oven dry subsamples at 50 °C or higher until a constant mass has been reached; record final dry mass. Use the ratio between subsample wet and dry mass to estimate dry mass of entire frond.
- Calculate the mean dry mass of palm fronds in kg. This value will be applied to scale up counts of palm fronds in plots.

Tiger ferns and similarly built species:

- These are small to medium sized, non-woody ferns and similarly built species. Because these are only recorded by count of clumps in the plots, a mean biomass is necessary to scale to carbon pool.
- Select 25-30 fern clumps from different individuals, outside of any sample plot. Include all common species in this sample.
- Cut clump at ground level and weigh it; record on datasheet.
- Take a manageable subsample from each clump and weigh. Record on datasheet. Clearly label with clump number.
- Oven dry subsamples at 50 °C or higher until a constant mass has been reached; record final dry mass. Use the ratio between subsample wet and dry mass to estimate dry mass of entire clump.
- Calculate the mean dry mass of fern clumps in kg. This value will be applied to scale up counts of fern clumps in plots.

Pandanus:

- Collect and analyze samples in the same manner as for *Nypa*. Each sample should be a clump of leaves and the stem leading to it.

Seedlings:

- These are trees that do not reach breast height (1.3 m). Because these are only recorded by count in the plots, a mean biomass must be used to scale to carbon pool.
- Select 25-30 seedlings from outside of any sample plot. Include all common species in this sample.
- Cut seedling at ground level and weigh it. Record on datasheet.
- For each seedling, separate wood and foliage and weigh separately. Record on datasheet.
- Take a manageable subsample from each cut seedling (of wood and foliage separately) and weigh. Record on datasheet; clearly label seedlings with number.

- Oven dry subsamples at 50 °C or higher until a constant mass has been reached; record final dry mass. Use the ratio between subsample wet and dry mass to estimate dry mass of entire seedling.
- Calculate the mean dry mass of seedlings in kg. This value will be applied to scale up counts of seedlings in plots.

<u>Goran</u>:

- One time during the field season, measure the actual base diameter of 30 stems for each of the 4 goran size classes. The 30 stems should come from different individuals. Calculate the quadratic mean diameter of each size class (see formula in woody debris harvest below).

<u>Herbaceous (forbs and grasses)</u>:

- Obtaining biomass of these components is not a priority since they are generally quite small. However, if desired during this or future surveys, allometric equations can be constructed relating percent cover to biomass per m^2. To do this, a one-time destructive harvest is necessary. Establish 20-25 temporary 2-m radius circular plots (similar to, but outside of, the actual survey plots), seeking a full range of percent covers. Make sure the low range of percent cover values (1-10%) is well represented. In each of these allometry plots, record the percent cover value, then clip all the herbaceous vegetation at ground level. Oven-dry at 50-70 °C to constant mass. Using a graphing or statistical program, create an allometric equation relating percent cover to biomass in kg per 12.6 m^2 (accounting for area of 2-m radius plot circle).

<u>Woody debris densities:</u>

- Field measurements are entered into equations that yield woody debris volume per area. To convert volume to biomass and carbon estimates, densities of woody debris are needed. Once during the field season, representative woody debris samples should be collected for each of the 5 categories: small, medium, large, extra-large (sound), extra-large (rotten). Collect 20-25 pieces of each size class, capturing a representative range of sizes within each class, and the full range of species to the degree recognizable. As a rough guideline, samples should have a mass of between ~0.5 and 50 g. Collection of pieces should be random/arbitrary, and not inside sample plots.
- Small, medium, and large collected pieces should be measured for diameter at mid-point. Calculate the quadratic mean piece diameter (QMD) for each size class separately. QMD is obtained by squaring each diameter (d),

summing the products, dividing by sample size (n), and taking the square root:

$$QMD = \sqrt{(\sum d_i^2)/n}$$

- All pieces from the five woody debris classes should then be measured for specific gravity (density).
  - To obtain specific gravity, first obtain piece volume. Fill a glass beaker ~2/3 full of water (enough to submerge each wood piece), zero the scale, then dip each piece one at a time into the water (while holding the piece with fine tweezers or blade tip; do not let the piece touch the bottom or sides of beaker). Because the specific gravity of water is 1 g cm^{-3}, the resultant increase in mass shown on the scale is the volume displaced by the particle. Record each piece volume. Do so immediately after dipping the piece in the water, as water absorption by the piece can make the volume readout drift downward.
  - Next obtain the oven-dry mass of each piece. Oven-dry at temperature of at least 50°C to constant mass, then record and circle the final dry mass values.
  - To obtain specific gravity, divide mass by volume for each piece. Calculate the mean specific gravity (g cm^{-3}) for each of the five woody debris classes. These mean values will be used in later computations of biomass/carbon.

LABORATORY AND DATA ANALYSIS

Laboratory Processing of Soils

Soil samples should be sent to a professional laboratory for analysis. It is recommended the selected laboratory be checked to ensure they follow commonly accepted standard procedures with respect to sample preparation (for example mixing and sieving) and carbon analysis methods.

<u>Bulk density samples</u>

If bulk density has not already been determined in the field, the laboratory should dry the bulk density samples at 105 °C for a minimum of 48 hours. Record the final oven-dry weight, minus the container weight.

NOTE: In the event that soils go to the lab in the hard-sided polypropylene collection containers, soils must be transferred to containers that are rated for high oven temperatures. The hard-sided polypropylene containers will melt at 105 °C.

NOTE: Do not dry the samples that will be used for %OC at any temperature greater than 50 °C; the extra drying in the lab is only for bulk density samples.

Rock fragments: If the sample contains rocky fragments (>2 mm diameter), these fragments should be retained and weighed separately, and these weights should be recorded.

<u>Nutrient samples: % organic carbon (%OC) determination</u>

Sample preparation: Sieve sample through a 2-mm sieve and then thoroughly mix. Grinding of the sample may be necessary. Make sure all 5 samples from a given depth interval in a plot are combined during this process.

Analysis: The dry combustion method using a controlled-temperature furnace (for example, a LECO CHN-2000 or equivalent[2]) is the recommended method for determining total soil carbon (TC), but the Walkley-Black method is also commonly used (Pearson et al. 2005).

If resources permit, separate the inorganic and organic fractions and report each. The organic fraction can be isolated by pre-treating the sample with HCl or H_2SO_4 to remove carbonates (inorganic C) before analyzing. Alternatively, a gravimetric technique can be employed to estimate the organic fraction through lower-temperature (400 °C) combustion. In either case, inorganic carbon is then estimated as the difference between total carbon (TC) and organic carbon (OC). There are also methods for direct determination of inorganic carbon. Each of these methods has advantages and disadvantages. See Schumacher (2002) for detailed discussion of these methods.

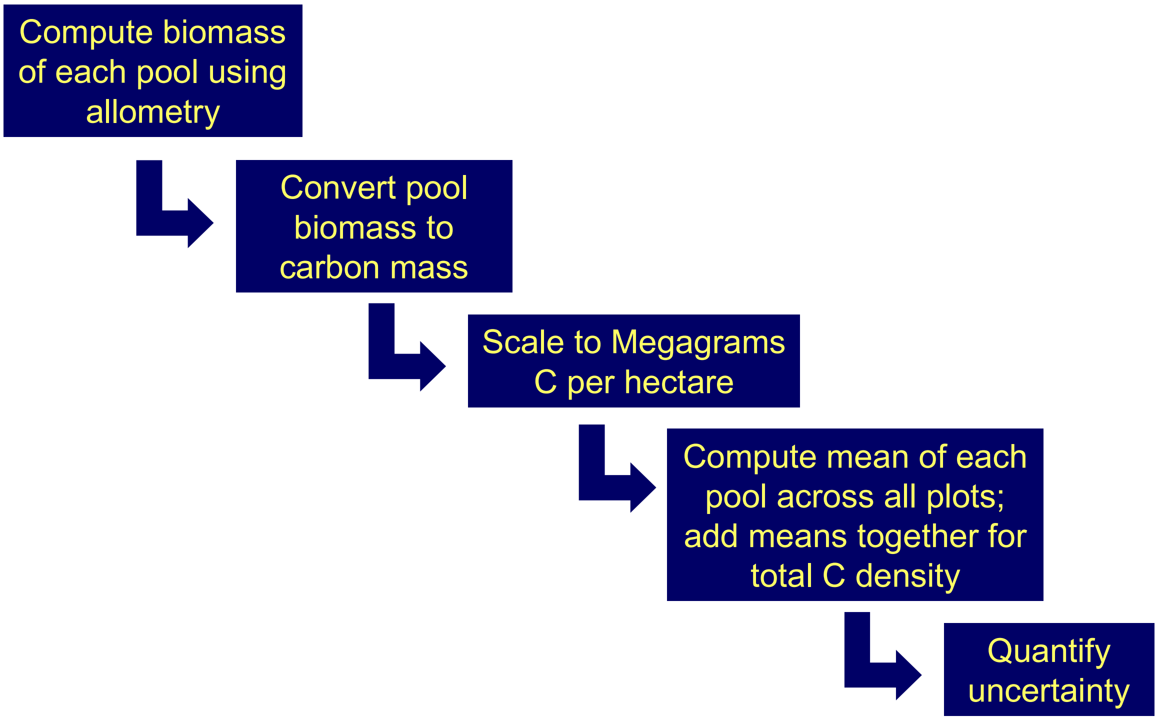
If this separation is not possible, use the total carbon value for soil C computations instead of organic carbon.

NOTE: Although %OC samples are not oven-dried at 105 °C, %OC must be reported on an oven-dry basis (based on the bulk density sample).

[2] The use of trade, firm, or corporation names in this document is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or Forest Service of any product or service to the exclusion of others that may be suitable.

Steps to Calculating Carbon Stocks

In basic form, the steps to calculating carbon stocks are:



Carbon Content of Biomass

Most calculations first determine the biomass of a given forest component, then convert to carbon pool. Since forest biomass is generally half carbon by mass, it is common practice to convert biomass to carbon by multiplying by 0.5:

$$\text{Carbon mass} = 0.5 * \text{Biomass}$$

NOTE: If local values for carbon content are available, these should be used instead of 0.5. In the future, calculated local values may be required.

Finally, soil is an exception to this conversion since soil carbon is measured directly. No conversion from biomass is necessary for soil.

Live Trees

Biomass equations relate dbh to biomass. Equations may be for individual species or groups of species, but this literature is inconsistent and incomplete. Before applying a biomass equation, consider its original location because trees in a similar functional group can differ greatly in their growth form between geographic areas. Also note the maximum diameter from which the equation was derived, as applying the equation to larger trees can lead to significant errors (large trees overestimated).

First, select a biomass equation. For mangroves, two widely applicable equations make this selection relatively easy. Chave et al. (2005) and Komiyama et al. (2008) each have general equations that can be used for mangrove trees across many regions. Each has advantages based on geography, diameter range, etc.; however we recommend the mangrove equation from Chave et al. (2005, page 93) because it agrees well with other mangrove equations and also handles larger diameters better (biomass estimates are less inflated for large trees). The equation is:

Equation for aboveground tree biomass:

$$\text{Aboveground biomass (kg)} = \rho * \exp(-1.349 + 1.980*\ln(\text{dbh}) + 0.207*(\ln(\text{dbh}))^2 - 0.0281(\ln(\text{dbh}))^3)$$

ρ = wood density (g cm^{-3})
-1.349 = constant
1.980 = constant
0.207 = constant
0.0281 = constant
dbh = tree dbh (cm)

Wood densities for live trees (which may be different from woody debris densities) are required for many biomass equations, including the general mangrove equations. These can be applied by species (preferable) or as a site-average wood density based on the species composition of dominant trees. Wood densities may be known by local forest agencies; if so, use these values. Otherwise, good sources for wood density include the World Agroforestry Database (http://www.worldagroforestry.org/sea/Products/AFDbases/WD/Index.htm), which reports densities in units of kg m^{-3} (divide by 1000 to obtain g cm^{-3}) or the primary literature. Two useful primary literature sources are Hidayat & Simpson (1994) and Simpson (1996; see Table C3, column G_b, values are in g cm^{-3}). A table of wood density for common Sundarbans tree species is included here.

Table 3. Wood densities of common tree species of Sundarbans.

Scientific name	Four-letter species code	Common name	Wood density ($g\ cm^{-3}$)
Avicennia officinalis	AVOL	Baen	0.740
Bruguiera gymnorhiza	BRGY	Kankra	0.970
Ceriops decandra	CEDE	Goran	0.960
Excoecaria agallocha	EXAG	Gewa	0.490
Heritiera fomes	HEFO	Sundri	0.730
Sonneratia apetala	SOAP	Keora	0.700
Xylocarpus granatum	XYGR	Dhundul	0.700
Xylocarpus mekongensis	XYME	Passur	0.725
Site average of above values	na	Mean density	0.752

Note: These values are from the World Agroforestry Database (see text). If more site-specific values are available, use those instead.

<u>To calculate tree biomass and carbon</u>:

- Plug the dbh and density of each tree into the biomass equation (default is mangrove equation from Chave et al. 2005, page 93). If species or wood density is unknown, use site average wood density in Table 3.
- Divide the resulting number by 1000 to convert to megagrams (Mg).
- Multiply by 0.5 to obtain Mg of carbon contained in the tree.

Example: a Sundri tree with dbh of 22 cm and wood density of 0.730 would be entered as follows:

Biomass calculation:

Aboveground Biomass (kg) $= \rho * \exp(-1.349 + 1.980*\ln(dbh) + 0.207*(\ln(dbh))^2 - 0.0281(\ln(dbh))^3)$

[Where ρ is wood density in g cm^{-3}, dbh is in cm]

Aboveground Biomass (kg) $= 0.730 * \exp(-1.349 + 1.980*\ln(22) + 0.207*(\ln(22))^2 - 0.0281(\ln(22))^3) = 271.6$ kg

Convert to Mg:

Aboveground Biomass (Mg) = 271.6/1000 = 0.2716 Mg

Convert to carbon:

Aboveground C mass (Mg) = 0.2716 * 0.5 = 0.136 Mg C

Lianas: Calculate liana biomass using a specific allometric equation for lianas, based only on dbh. See Appendix 2 for equation. Once biomass is calculated, convert to Mg C by multiplying by 0.5.

Palms with woody stems (e.g., hental): Calculate biomass using a specific allometric equation for woody palms, based only on height. See Appendix 2 for equation. Once biomass is calculated, convert to Mg C by multiplying by 0.5.

Finally, add all the individual tree C masses together within each plot (including all trees, lianas, and woody palms), to obtain total tree aboveground C mass in each plot. Scale to aboveground tree C mass per hectare by dividing by the plot area, which for trees is $5*\pi(10^2)$, and multiplying by 10,000 to convert m^2 to hectares. This yields aboveground tree C density in Mg ha^{-1}.

Example of tree C computation:

Sundri	0.136 Mg C	Scale to Mg per hectare:
Gewa	0.125 Mg C	
Liana	0.082 Mg C	[0.444 Mg C / $(5*3.14*10^2)$] * 10,000
Sundri	0.101 Mg C	
Plot Total =	0.444 Mg C	$\boxed{= 2.83 \text{ Mg C ha}^{-1} \text{ of trees}}$

Note on slope correction: In upland forests, a correction factor for plots on sloping ground is implemented so that all per-hectare carbon values are reported on a horizontal projection. This slope correction is an important step for scaling up to per-hectare values. See Pearson et al. (2005) for a description of these corrections. For mangroves, which are generally flat, slope correction is unnecessary.

Alternative allometries and historic data

Note: If comparing current data with historic data, it is best to use consistent formulas among censuses, to the extent possible. Selection of allometric equations should be as consistent as possible for past, present, and future censuses.

There are also methods for converting stand tables or stock tables of merchantable volume to biomass, which may be useful if that is the only data type available from past inventories. These are called biomass conversion and expansion factors (BCEF) and are considered adequate but less accurate than direct biomass equations. BCEF's are explained in sufficient detail on pages 2-56 through 2-57 of the GOFC-GOLD sourcebook; see also Pearson et al. (2007). Similarly, allometric equations for merchantable volume of individual trees, which already exist for Sundarbans forests (Chaffey et al. 1985), can be used, followed by multiplying by wood density and a factor of 1.2 to account for branches and leaves. This method is considered less accurate than direct biomass equations.

Belowground Biomass of Trees

The most efficient way to obtain belowground root biomass is to apply widely accepted general models (Pearson et al. 2005). Unlike the aboveground equation, the belowground equation is not applied at the individual tree level. Instead it is applied at the plot level. Belowground biomass density of trees in the plot is a function of their aboveground biomass density in the plot:

Equation for tree belowground biomass density:

$$BBD = \exp(-1.0587 + 0.8836 * \ln(ABD))$$

BBD = belowground biomass density (Mg ha^{-1})
-1.0587 = constant
0.8836 = constant
ABD = aboveground biomass density (Mg ha^{-1}). Obtain ABD by multiplying aboveground tree C density (Mg ha^{-1}) by 2.

Multiply BBD by 0.5 to obtain C mass.

No scaling is necessary since the aboveground biomass value is already scaled to the hectare.

Example of belowground tree computation:

Aboveground C density = 120 Mg ha^{-1}
Aboveground Biomass Density (ABD) = 120 * 2 = 240 Mg ha^{-1}

$$BBD = \exp(-1.0587 + 0.8836*\ln(240))$$

$$BBD = 44.0 \text{ Mg ha}^{-1}$$

$$\text{Belowground C density} = 44 * 0.5 = \boxed{22 \text{ Mg ha}^{-1}}$$

Standing Dead Trees

Standing dead trees are estimated for biomass in two different ways, corresponding to the two decay status categories.

Decay status 1 trees (recently dead) can be estimated for biomass in similar fashion as live trees:

- Insert the wood density and dbh into the same equation as for live trees.
- Subtract out the biomass of leaves (2.5 percent of aboveground biomass).
- Divide by 1000 to obtain Mg.
- Multiply by 0.5 to obtain C mass.

Decay status 2 trees (no twigs/small branches) may be calculated in a number of ways. We recommend the following method for its relative ease. Using the basal diameter measurement, apply the taper equation to estimate the diameter at the top of the dead tree:

Taper Equation:

$$d_{top} = d_{base} - \left[100 * ht * \left(\frac{d_{base} - dbh}{130} \right) \right]$$

d_{top} = estimated diameter at top of tree (cm)
d_{base} = the measured basal diameter (cm)
ht = tree height (m)
dbh = tree dbh (cm)

Then estimate the volume by assuming the tree is a truncated cone:

Equation for volume of decay status 2 trees:

$$\text{Volume (cm}^3\text{)} = \left(\frac{\pi * (0.01*ht)}{12}\right) * (d^2_{base} + d^2_{top} + (d_{base} * d_{top}))$$

ht = tree height (m)
d_{base} = the basal diameter (cm)
d_{top} = the diameter at the top (cm) estimated from the taper equation (if taper equation results in negative number, use 0 for d_{top}).

Next, use species-specific or average wood density (Table 3) to convert volume to biomass. Sound wood density can be used because the wood must be reasonably sound to support the standing tree (Pearson et al. 2005). The conversion equation is:

$$\boxed{\text{Dead tree biomass (g)} = \text{volume (cm}^3\text{)} * \text{wood density (g cm}^{-3}\text{)}}$$

- Because the biomass is in g rather than kg, divide by 1,000,000 to obtain Mg.
- Multiply by 0.5 to obtain C mass.

Finally, add all the dead tree C masses together within each plot. Scale to dead tree C mass per hectare by dividing by plot area ($5*\pi*10^2$) and multiplying by 10,000 m^2 ha^{-1}. Refer to example box for tree C computations above.

Live Saplings and Seedlings

Saplings:

- Insert the dbh and wood density of each sapling into the dbh-density biomass equation (default is dbh-density mangrove equation from Chave et al. 2005, page 93). If species or wood density is unknown, use site average density in Table 3.
- Include small (<5 cm dbh) lianas in these calculations. Use the liana allometric equation in Appendix 2.
- Divide the resulting number by 1000 to convert to megagrams (Mg).
- Multiply by 0.5 to obtain Mg of carbon contained in the sapling.

Seedlings:

- Multiply the count of seedlings in the plot by the average biomass per seedling (determined by destructive harvest, see above).
- Convert to megagrams (Mg).
- Multiply by 0.5 to obtain Mg of carbon contained in all the seedlings.

Sapling/Seedling aboveground C density:

Finally, add all the sapling C masses together, then add in the total seedling C mass. Scale to sapling/seedling C mass per hectare by dividing by plot area, which is $5*\pi*3^2$, then multiplying by 10,000 m^2 ha^{-1}. Refer to example box for tree C computations above.

Belowground Biomass of Saplings and Seedlings

Repeat the process as for trees. Belowground biomass density of saplings and seedlings in the plot is a function of their aboveground biomass density in the plot:

Equation for sapling/seedling belowground biomass density:

$$BBD = \exp(-1.0587 + 0.8836*\ln(ABD))$$

BBD = belowground biomass density of sapling/seedling (Mg ha^{-1})
-1.0587 = constant
0.8836 = constant
ABD = aboveground biomass density of sapling/seedling (Mg ha^{-1}). Obtain ABD by multiplying the sapling/seedling aboveground C density by 2.

Multiply BBD by 0.5 to obtain C mass.

No scaling is necessary since the value is already scaled to the hectare.

Refer to example box for tree C computations above.

Dead Saplings and Seedlings

Dead saplings can be estimated for biomass in similar fashion as live saplings:

- Insert the wood density and diameter into the same equation as for live trees.
- Subtract out the biomass of leaves (5 percent of aboveground biomass).
- Divide by 1000 to obtain Mg.
- Multiply by 0.5 to obtain C mass.

Dead seedlings can be estimated for biomass in similar fashion as live seedlings:

- Multiply the count of dead seedlings in the plot by the average biomass per seedling (determined by destructive harvest, see above).
- Subtract out the biomass of leaves (10 percent of aboveground biomass).
- Divide by 1000 to obtain Mg.
- Multiply by 0.5 to obtain Mg of carbon contained in all the dead seedlings.

Finally, add all the dead sapling C masses together, then add the total dead seedling C mass. Scale to dead sapling/seedling C mass per hectare by dividing by plot area, which is $5*\pi*3^2$, then multiplying by 10,000 m^2 ha^{-1}. Refer to example box for tree C computations above.to example box for tree C computations above.

Non-Tree Vegetation

Non-woody palms, ferns, etc.:

- Multiply the count of stems of *Nypa* in the plot by the average biomass per frond (determined by destructive harvest, see above).
- Divide by 1000 to obtain Mg.
- Multiply by 0.5 to obtain Mg of carbon contained in all the *Nypa* fronds in the plot.
- *Repeat* for tiger fern (by clump), *Pandanus*, and any other species recorded.

Add all these together within each plot. Scale to non-tree vegetation C per hectare by dividing by plot area, which in this case is $5*\pi*4^2$, and multiplying by 10,000 m^2 ha^{-1}.

Goran:

- Enter the quadratic mean diameter of each size class (determined during a one-time field measurement, see above) into the allometric equation for goran biomass, which was developed during the 1995 inventory:

$$\text{Biomass (kg)} = 1.337 - 0.8816*D + 0.3876*D^2$$

- Multiply the resulting biomass by the count of stems in each size class.
- Divide by 1000 to obtain Mg.
- Multiply by 0.5 to obtain Mg of carbon contained in all the goran in the plot.
- Scale to goran C per hectare by dividing by plot area, which is $5*\pi*2^2$, and multiplying by 10,000 m^2 ha^{-1}.

Note: If herbaceous vegetation biomass is of interest in the future:

- Calculate forb biomass by entering % cover value into allometric equation to obtain biomass per 12.6-m^2 subplot (the area of the 2-m radius nest). Add the five subplot values together within the plot. Convert to units of Mg, convert to carbon mass.
- Repeat for grasses.
- Convert to C mass per hectare by dividing by plot area and multiplying by 10,000.

Forest Floor

Forest floor (litter) is unlikely to be collected for this project. However, if this decision is changed in the future and it is to be quantified, apply the following steps:

- If subsamples were taken to determine moisture content for some plots, multiply the original sample wet mass by these subplot-specific dry:wet ratios. The result will be the estimated dry mass of the original sample.
- Add total dry mass of all 5 litter collections from each plot.
- Convert to Mg. Multiply by 0.5 to obtain Mg C mass.
- Scale to litter biomass per hectare by multiplying by expansion factor 10000/(5*0.3*0.3) = 22 222

Canopy Cover

To obtain canopy cover estimates from the densiometer readings:

- Multiply the recorded counts by 1.04 to obtain the percent of area not occupied by canopy. This is because there were only 96 dots to count, instead of 100.
- Subtract the resulting value from 100 to obtain canopy cover in percent.
- Average the 4 values from each subplot (N, S, E, W) to provide a mean estimate of canopy cover at each subplot.

Finally, average the 5 subplot means to obtain a plot-average canopy cover.

Woody Debris

Small, medium and large size classes:
For small, medium, and large classes, these data were collected as counts only. Therefore, use the quadratic mean diameter for each class. The volume equation for these classes is:

Equation for volume of small, medium and large woody debris classes:

$$\text{Volume } (m^3\ ha^{-1}) = \pi^2 * \left(\frac{N_i * QMD_i^2}{8 * L} \right)$$

N_i = the count of intersecting woody debris pieces in size class i
QMD_i = the quadratic mean diameter of size class i (cm) (see destructive harvest)
L = transect length for that class (m).

For size class small:	L = 2 m
For size class medium:	L = 5 m
For size class large:	L = 10 m

Extra-large size class:
For extra-large woody debris classes, volume per hectare is calculated by the formula:

Equation for volume of extra-large woody debris classes:

$$\text{Volume } (m^3\ ha^{-1}) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + d_3^2 + \ldots . d_n^2}{8 * L} \right)$$

d_1, d_2, etc. = diameters of intersecting pieces of dead wood (cm)
L = the length of the transect line for a given class (m). For size class extra-large (sound, rotten), L = 10 m

Next, convert volume to biomass for all 5 classes of woody debris using class-specific wood densities. These densities were obtained via the one-time destructive harvest of woody debris (see destructive harvest above). Calculate separately for each class:

$$\boxed{\text{Woody Debris Biomass } (Mg\ ha^{-1}) = \text{Volume } (m^3\ ha^{-1}) * \text{Wood density } (g\ cm^{-3})}$$

Finally, add the 5 classes together to get a single value for total woody debris on each transect. Multiply biomass by 0.5 to obtain woody debris C mass per hectare on each transect. *Average* all 20 transects across the plot.

Soil

First obtain the bulk density of each soil layer within each plot. This is determined by dividing the oven-dry soil sample by the volume of the sample. The bulk density equation is:

Equation for soil bulk density:

$$\text{Soil bulk density (g m}^{-3}\text{)} = \frac{\text{Oven-dry sample mass (g)}}{\text{Sample volume (m}^3\text{)}}$$

- If rocks (mineral particles > 2mm diameter) were present in the sample, these should have been separated and weighed in the laboratory. A correction factor is then included in the equation:

Equation for soil bulk density when rocks are present:

$$\text{Soil bulk density (g m}^{-3}\text{)} = \frac{\text{Oven dry mass (g)}}{\text{Sample volume (m}^3\text{)} - \left(\dfrac{\text{Mass of rock fragments (g)}}{2.65 \times 10^6 \text{ g m}^{-3}}\right)}$$

Where 2.65×10^6 g m^{-3} is the default density of rock fragments (Pearson et al. 2005).

- *Sample volume*: If soils were collected using the open-face peat auger, the sample volume is obtained by the following calculation:

Equation for soil sample volume using open-faced peat auger:

$$5 * \text{Sample length collected} * \left(\pi * r^2 - \left(\frac{r^2}{2} * \left(\frac{\pi}{180}\theta - \sin\theta\right)\right)\right)$$

Where the factor of 5 accounts for five subplots
sample length collected (in m) = the length of the soil sample that was collected from the auger and taken from the field
r = the radius of the auger (in m)
θ the angle (in degrees) indicated in the figure below

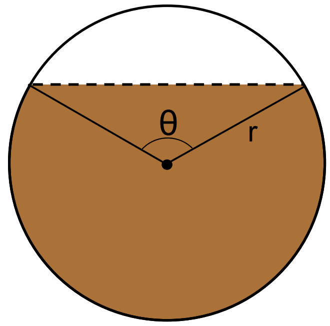


Figure 17. *Cross-section of open-face soil auger.*

For the auger used in this survey, sample length collected = 0.05 m, r = .0275 m and θ = 119.5°. The resulting sample volume is:

$$5 * 0.05 * \left(\pi * 0.0275^2 - \left(\frac{0.0275^2}{2} * \left(\frac{\pi}{180} * 119.5 - \sin(119.5)\right)\right)\right)$$

This results in a sample volume of 0.0003833 m^3.

- If soils were collected using the slide hammer, the sample volume is obtained by the simple formula for the volume of a cylinder with radius 0.0240 m and height of the sample sleeve (0.05 m), and multiplied by 5 because of five subplots:

Sample volume if slide hammer used = $5 * (\pi * 0.0240^2 * 0.05) = 0.000362\ m^3$

Calculating soil C mass per hectare:

Using the %OC data obtained from the laboratory, the amount of carbon per unit area is given by:

Equation for soil carbon per hectare:

Soil C (Mg ha^{-1}) = bulk density (g m^{-3}) * soil depth interval (m) * %OC * 0.01

Soil depth interval = 0.3 for 0-30 cm depth interval, and 0.7 for 30-100 cm interval
%OC is expressed as a decimal fraction (e.g., 5% is expressed as 0.05)
0.01 = a conversion factor to convert units to Mg ha^{-1}

Perform the above calculation for the 0-30 cm depth interval, repeat for the 30-100 cm depth interval. Add the values together to obtain total soil C (Mg ha^{-1}) for the top meter of soil.

Total Carbon Density and Total Carbon Stock

<u>Total Carbon Density and Carbon Stock</u>

The total carbon density at time t (i.e., resulting from a census in a given year) is estimated by adding all of the component pools.

- First, calculate the mean carbon density (Mg ha^{-1}) for each component pool (e.g., trees, soil, etc.). For this survey, this requires summing the C mass (Mg ha^{-1}) across all inventory plots and dividing the sum by the number of plots.

- Total carbon density is estimated by summing the mean carbon density for all component pools across the study area in Mg ha^{-1}:

Equation for total carbon density:

Total C density (Mg ha^{-1}) =

$$C_{treeAG} + C_{treeBG} + C_{deadtree} + C_{sap/seed} + C_{sap/seedBG} + C_{deadsap/seed} + C_{nontreeveg} + C_{woodydebris} + C_{soil}$$

Note: Check that total carbon densities are within a reasonable range; most forests have C density on the order of tens to hundreds of Mg C per hectare including above- and belowground pools (commonly between ~50-500 Mg C ha^{-1}). Values far outside of this range should be given extra scrutiny.

- Total carbon stock of SRF is then estimated by multiplying this mean carbon density by the forested area of the reserve (i.e., the project area):

Equation for total carbon stock of a given project area:

Total carbon stock of SRF (Gg) = Total C density (Mg ha^{-1}) * $Area_{SRF}$ (ha) * 0.001

The factor of 0.001 is used to convert Mg to Gg (10^9 grams), which is a common reporting unit for total carbon stocks, per IPCC guidelines. Other units are acceptable too, but take care to track which units are used.

Combining with Activity Data:

One approach is to use remote sensing activity data to quantify the amount of land area in general classes (e.g., intact forest, non-intact forest, other land use), then multiply these land area values by the C density in each of the classes to obtain C stock by class. The C density by class would be obtained by performing the above calculations within each of the land classes. The resulting C stocks in each class would then be added together to obtain total C stock for the project area.

Converting to CO_2 equivalents

Greenhouse gas inventories (and emissions) are often measured in CO_2 (carbon dioxide) equivalents, as this is the most common greenhouse gas form of carbon. Deforestation and forest degradation result in greenhouse gas emissions dominated by CO_2, with other trace gases such as CH_4 also being released.

If desired or required for reporting purposes, the total carbon density and total carbon stock can be converted to CO_2 equivalents by multiplying C density or stock by 3.67. This is the ratio of molecular weights between carbon dioxide [44] and carbon [12]. The example of total C stock is shown below:

Equation for converting total carbon stock to CO_2 equivalents:

$$\text{Total C stock (Gg } CO_2 \text{ equivalents)} = 3.67 * [\text{total C stock (Gg C)}]$$

If a substantial portion of land-based greenhouse emissions are in the form of methane (CH_4) or nitrous oxide (N_2O), then different conversions are required to obtain CO_2 equivalents. This is because these trace gases have much stronger greenhouse effects than CO_2, typically by orders of magnitude. Therefore, higher conversion factors would be required. For ecosystems such as Sundarbans, relatively little information is available on the ratios of different forms of C emissions, so a default conversion of 3.67 can be used (GOFC-GOLD 2009). See GOFC-GOLD (2009) sourcebook for more information.

Quantifying & Reporting Change in C Pools Over Time

Carbon assessments aim to quantify changes in C pools over time. Two equally valid approaches are used to estimate these changes: stock-change and gain-loss. The stock-change approach estimates the difference in carbon stocks at two points in time, while the gain-loss approach estimates the net balance of additions to and removals from a carbon stock. The stock-change approach is used when carbon stocks in relevant pools have been measured and estimated over time, such as in forest inventories. The gain-loss approach is used when annual data such as biomass growth rates and reliable data on wood harvests are available. In practice, a mix of the two approaches may be used.

This protocol focuses on forest inventory approaches in support of high-tier C assessments. The stock-change approach is emphasized here. Stock-change is an acceptable method for estimating emissions caused by both deforestation and forest degradationin all C pools (GOFC-GOLD 2009). The C stock of a pool at time 1 will represent the initial condition (e.g., intact forest), and the C stock of that pool at time 2 will be the value for the pool under 1) no change—intact forest, 2) the new land use—deforestation, or 3) the non-intact forest (degradation).

To calculate the change in C stocks over a given time period, the C density of each pool at the beginning of the time period is subtracted from the C density at the end of the time period, then divided by the time period length:

Equation for pool-specific change in carbon over a given time period:

$$\Delta C = C_{t2} - C_{t1}$$

ΔC = Change in carbon density of pool (Mg C ha^{-1})
C_{t2} = Carbon density of pool at time 2 (Mg C ha^{-1})
C_{t1} = Carbon density of pool at time 1 (Mg C ha^{-1})

Note that the equation is applied separately for each C pool; e.g., trees, soil, etc. These changes are then summed across all pools to obtain an estimate of change in total C density:

Equation for total change in carbon density over a given time period

$$\Delta C_{total} = \Delta C_{c1} + \Delta C_{c2} + \Delta C_{c3} + \ldots\ldots \Delta C_{cn}$$

ΔC_{total} = Change in total carbon density (Mg C ha^{-1})
ΔC_{c1} = Change in carbon density of pool 1 (Mg C ha^{-1})
ΔC_{c2} = Change in carbon density of pool 2 (Mg C ha^{-1})
etc.

To obtain the change in total C stock, the change in total C density is then multiplied by the project area:

Equation for total change in carbon stock over a given time period:

ΔC_{stock} (Mg C) = ΔC_{total} (Mg C ha^{-1}) * Project Area (ha)

To obtain the annual C emission rate over the time period, the change in total carbon stock is then divided by the length of the time period in years:

Equation for annual carbon emission rate over given time period:

$$\text{Annual C emission rate (Mg ha}^{-1}) = \Delta C_{stock} / (t_2 - t_1)$$

ΔC_{stock} = Change in total carbon stock [emission rate] (Mg C yr^{-1})
t_1 = beginning of time period (year)
t_2 = end of time period (year)

Finally, if required, convert values to CO_2 equivalents by multiplying by 3.67.

Note that soils may be tracked somewhat differently using a combination of stock-change and gain-loss approaches, based on several necessary assumptions for soil C when forest land is degraded or converted to other use. See p. 2-77 and 2-78 of GOFC-GOLD (2009) for assumptions and equations for integrating gain-loss for soils. Methods for monitoring mangrove soil carbon with land-use change are not well established.

Combining with activity data:

The sample plots may capture changes in C pools with land use, if plots are in areas where deforestation and/or degradation are occurring. The field data from these plots would then provide information on the fate of C pools upon deforestation or degradation (emission factors). This information could then be combined with remote-sensing activity data on land use changes occurring such as forest land converted to other use (deforestation) or forest land converted from intact to non-intact (degradation). In this manner, activity data and emission factors can be used to assess changes in total C stock over the changed area. The equation for this is:

Equation for change in carbon stock in land converted to new land-use:

$$\Delta C_{CONV} = \sum \left[(C_{AFTER} - C_{BEFORE}) * \Delta A \right]$$

ΔC_{CONV} = change in C stock on land converted to different use (e.g., intact forest to other use)
C_{AFTER} = C density on converted land immediately after conversion
C_{BEFORE} = C density on converted land immediately before conversion
ΔA = area of converted land

This calculation can be carried out and summed for all combinations of land-use change (e.g., intact to non-intact forest, intact forest to other land-use, non-intact forest to other land-use; see Figure 1).

Example: Remote sensing indicates that, between time 1 and time 2, 3000 hectares of intact forest within the project area were converted to other land-use such as agriculture. For example purposes, assume that C density of intact forest is 300 Mg ha^{-1} and agricultural land is 100 Mg ha^{-1}. Solving for the above equation yields an estimate of change in C stock due to deforestation of [(100-300) * 3000] = -600,000 Mg C. In other words, a loss of 600,000 Mg C, or 2 202,000 Mg CO_2 equivalent.

Quantifying Uncertainty in Carbon Pools

For carbon assessments it is essential that not just the mean, but also the uncertainty is estimated and reported. Uncertainty reflects the degree of precision in the dataset (i.e., how much variation there is around the mean value). For carbon assessments it is typically reported as a 95% confidence interval (CI), expressed as a percentage of the mean. For example, if the value is 100 Mg ha^{-1} and the 95% CI is 90-110 Mg ha^{-1}, the uncertainty in the estimate is ±10%.

Key definitions relevant to uncertainty should be reviewed on pages 2-92 through 2-93 of GOFC-GOLD (2009).

Uncertainty should be quantified and reported for each component pool as well as total carbon density and total carbon stock.

<u>Uncertainty in Component Pools</u>

The first step is to compute a 95% confidence interval (CI) for each component pool (trees, soil, etc.). For practical purposes, the 95% CI is the mean plus or minus 2 x the standard error of the mean. To get the standard error, first compute the standard deviation (*s*) as:

Equation for standard deviation of a mean:

$$\text{Standard deviation of the mean (s)} = \sqrt{\sum_{i=1}^{n} (Y_i - \overline{Y})^2 / (n - 1)}$$

Y_i = value of the *i*th plot,
$\overline{Y}$ = mean value of all plots,
n = the number of plots.

Most statistical or spreadsheet programs easily compute the standard deviation. Next, compute standard error as:

Equation for standard error of a mean:

$$\text{Standard error of the mean (SE)} = \frac{s}{\sqrt{n}}$$

s = standard deviation of mean,
n = number of plots

The ‘half-width’ of the 95% CI is then computed by:

95% CI half-width = 2 * SE

The 95% CI half-width is then added to and subtracted from the mean. For example if the mean is 200 Mg ha^{-1} and the 95% CI half-width is 10, the 95% CI is 190-210 Mg ha^{-1}.

The 95% CI half-width is also used to express the uncertainty as a percentage of the mean.

Uncertainty (%) = 100* (95% CI half-width) / mean.

In the above example, uncertainty = 100*(10)/200 = 5%.

<u>Uncertainty in Total Carbon Density</u>

Total carbon density is the sum of several pools, each of which has its own uncertainty. Therefore, calculating uncertainty in total carbon density requires accounting for the uncertainty in each of the component pools.

There are two methods for calculating the total uncertainty for carbon projects (Pearson et al. 2005, Pearson et al. 2007, GOFC-GOLD 2009). The first method uses simple error propagation through the square root of the sum of the squares of the component errors. The second method uses Monte Carlo simulations to propagate errors.[3] The advantage of the first method is that it is simple to use and requires no additional computer software. However, the second method is used when substantial correlations exist between datasets (for example, between two carbon pools), when uncertainties are very large (e.g., greater than 100%), or when data distributions are strongly non-normal. In theory, it is always better to use Monte Carlo simulations because it is robust to most any data structure; thus, if data analysts knowledgeable of this method are available, this is the preferred approach. Nevertheless, in practice the difference in results attained through the two methods is typically small unless correlations and/or uncertainties are very high (Pearson et al. 2007). For practical purposes, the simple error propagation method is often used. The error propagation method is detailed here for its ease of use.

For total carbon density, the formula for the 95% CI half-width is:

Equation for uncertainty in total carbon density:

$$\text{95\% CI half-width for total C density} = \sqrt{([95\%CI_{c1}]^2 + [95\%CI_{c2}]^2 + \ldots\ldots\ldots\ [95\%CI_{cn}]^2)}$$

Where $[95\%CI_{c1}]$ is the 95% CI half-width for pool 1, e.g., tree C mass, pool 2, and so on for all pools measured in the plots.

The total uncertainty in C density can either be expressed as the actual confidence interval (e.g., mean = 300, 95% CI = 270-330), or as a percentage of the mean (e.g., 300 ± 10%).

Uncertainty in Total Carbon Stock

The error propagation technique for total C stock is the same general concept as for total C density. However, the formula for error propagation is slightly different

[3] The principle of Monte Carlo analysis is to perform the summing of uncertainties many times, each time with the uncertain components chosen randomly by Monte Carlo software from within the distribution of uncertainties input initially by the user. Examples of Monte Carlo software include Simetar, @Risk, or Crystal Ball (www.simetar.com, www.palisade.com/html/risk.asp, www.crystalball.com).

because the estimate of interest requires multiplication rather than addition of inputs (see equation for total C stock above).

The remote sensing analysis of land cover types (e.g., forest, grassland, etc.) should have an uncertainty estimate associated with it. For example, the forested area of SRF may be estimated at 400,000 ha ± 30,000 ha.

Combine this uncertainty with the uncertainty in total C density by the equation:

Equation for uncertainty in total carbon stock:

$$\text{95\% CI half-width for total C stock} = \text{area} * \text{TCD} * \sqrt{\left(\left[95\%CI_{area} / \text{area}\right]^2 + \left[95\%CI_{TCD} / \text{TCD}\right]^2\right)}$$

Area = estimated land area in a given category (e.g. forest),
TCD = mean total carbon density within that category,
$95\%CI_x$ = the uncertainty of each parameter (expressed as 95%CI half-width).

For example, if the forested area is estimated at 400,000 ± 30,000 ha, and the TCD is 300 ± 30 Mg ha^{-1}, the total C stock would be reported as 400,000 ha * 300 Mg ha (= 120,000,000 Mg, or 120,000 Gg). The uncertainty around this value is computed as follows:

$$\text{95\% CI half-width for total C stock (Mg)} = 400\,000 * 300 * \sqrt{\left(\left[30\,000 / 400\,000\right]^2 + \left[30 / 300\right]^2\right)}$$

$$= 15{,}000{,}000 \text{ Mg} \quad \text{or} \quad 15{,}000 \text{ Gg}$$

Like total carbon density, the uncertainty in total carbon stock can be expressed as the actual interval, or as a percentage of the mean estimate.

Thus, the total C stock would be reported as 120,000 ± 15,000 Gg. Or, 120,000 Gg ± 12.5%.

Uncertainty in Carbon Stock Change

Changes in carbon stocks over time should also have a quantified uncertainty. For the stock-change approach, this can be accomplished in a series of error-propagation steps:

- Compute the change in C density for each pool by subtracting the C density at time 1 from the C density at time 2 (see stock-change equation above).
- Compute the uncertainty in change of each C pool by the equation:

Equation for uncertainty in carbon pool change:

$$\text{95\% CI half-width for change in C pool} = \sqrt{([95\%CI_{t1}]^2 + [95\%CI_{t2}]^2}$$

$95\%CI_{t1}$ = 95% CI of the pool at time 1,
$95\%CI_{t2}$ = 95% CI of the pool at time 2.

- Add the changes for all C pools together to estimate change in total C density (as described in previous section).
- Compute the uncertainty for change in total C density by the equation:

Equation for uncertainty in total carbon density change:

$$\text{95\% CI half-width for change in total C density} = \sqrt{([95\%CI_{\Delta c1}]^2 + [95\%CI_{\Delta c2}]^2 + \ldots\ldots\ldots [95\%CI_{\Delta cn}]^2)}$$

$95\%CI_{\Delta c1}$ = 95% CI of the change in pool 1,
$95\%CI_{\Delta c2}$ = 95% CI of the change in pool 2, etc.

- Compute the uncertainty for change in total C stock over the project area by combining uncertainty in total C density with uncertainty in project area:

Equation for uncertainty in change in total carbon stock over the project area:

$$\text{95\% CI half-width for change in total C stock} = \text{area} * \Delta TCD * \sqrt{([95\%CI_{area} / \text{area}]^2 + [95\%CI_{\Delta TCD} / \Delta TCD]^2)}$$

Area = estimated land area in a given category (e.g. forest),
ΔTCD = mean total carbon density within that category,
$95\%CI_x$ = the uncertainty of each parameter (expressed as 95%CI half-width).

Note on Stratification

Note that if the landscape of interest was stratified (e.g., into different forest or land cover types), then the above computations of individual C components, total C density, total C stock, and C stock change must be conducted for each stratum separately. These separate computations are then added together to get total C estimates. Uncertainty is also calculated for each stratum, then propagated to get total uncertainty using the additive equation outlined above.

Notes on Establishing a Baseline

The baseline is the historic rate of change in carbon stocks, or the carbon emissions, from a given project area. Forest carbon projects must compare actual future carbon emissions with modeled future emissions based on this baseline rate, which is often referred to as a 'business as usual' scenario. Changes in C stocks/emissions due to the carbon project (e.g. marketable carbon benefits) are quantified as departures from the baseline business as usual scenario.

In general, the two main data types—activity data and emission factors—need to be assessed for an approximately 10-20 year period prior to project initiation.

Methods for establishing the baseline vary and no single method is the absolute standard; these are still under discussion and development at the international level. A typical time period for the baseline is 10-20 years prior to project initiation (e.g., 1995 – 2005 or 1995 – 2010). Some flexibility may be employed in order to utilize past datasets, for example previous forest inventories.

For SRF, forest inventories were conducted in 1985 and 1995. Some of these data can be used to compute C stocks at those times. Depending on the scope of data collected, changes in C stocks for the period 1995 - 2010 could be assessed based on comparison of the most recent and current inventory. This assessment would hopefully identify any past trends in forest C stocks over the project area due to, for example, forest degradation. This information would support quantification of emission factors due to degradation and possibly deforestation (if deforested areas were part of the sample).

The methods outlined in this document for computing carbon stocks from forest inventories could be used for these assessments:

- Obtain previous datasets, which were likely focused on trees, the dominant aboveground C pool.
- Apply biomass and C equations as outlined here for the current inventory. Alternatively, apply BCEFs based on timber volume data (see box above and GOFC-GOLD 2009, pages 2-55 to 2-59).
- Combine these with activity data on land use / land cover to estimate total C stocks at each time point.
- Compare C stocks between inventory years using the stock-change approach. This provides the estimate of baseline C emissions.
- *NOTE*: To the extent possible, use consistent methodologies for computing C stocks at each time point, including the current inventory. Decisions on approach will need to take into account which pools were measured in a given census (i.e., non-tree pools and soil were likely not measured in the past, so these may need to be excluded from the baseline, or their rates of

change estimated based on trends in trees or other scientific sources on these pools). Similarly, selection of allometric approaches (allometrics based on dbh-density only, or dbh-density-height, or BCEFs) should be made as consistent as possible. Conservativeness and transparency in methodology and assumptions are essential.

Remote sensing data and other land cover information must be used to obtain activity data. The specifics of these methods are beyond the scope of this document, but the basic concept is that changes in forest cover, land use, and forest degradation (see Figure 1) are quantified over the time period of interest by comparing time 2 to time 1 (e.g., 1995-2010). These data are combined with C density data in each cover type to estimate changes in total C stocks during the baseline period.

Ideally, uncertainty is also quantified around the mean baseline estimate using the same general approaches as for current C stocks (above). The difference from the baseline (carbon benefit) has a 95% CI associated with it that can be computed by propagating the uncertainty of the baseline projection and the actual C stock at a given time point. Applying the principle of conservativeness (risk of overestimating reduction in emissions should be minimized), the lower confidence bound of this uncertainty interval may be the chosen estimate of emission reduction. See page 4-182 of GOFC-GOLD (2009).

Quality Assurance / Quality Control and Verification

A rigorous quality control / quality assurance (QA/QC) and verification program ensures that all possible measures have been taken to guarantee that high quality data have been collected and can be reproduced. This will be especially important when participating in an international carbon credit market. Qualities of transparency, consistency, comparability, completeness and accuracy are vital.

<u>QC</u> is largely an internal activity performed as part of routine data collection and analysis. These measures should be taken and documented every day that data collection and analysis occurs. Most QC activities are easy to implement, such as reviewing data sheets at the end of a day in the field for completeness, legibility and accuracy, and fixing any mistakes right away. Timely and consistent review of the data also allows any broader problems in data collection and/or entry to be corrected.

<u>QA</u> refers to review procedures performed by persons not directly involved in the data collection and analysis, after the inventory and QC procedures have been completed. Ideally an independent third party completes the QA. QA is designed to verify that the QC activities were effective and that the data collected are of the best possible quality.

Verification activities are designed to ensure reliability of both the methodology and data collected. These procedures are external to the inventory, and use an independent data set. The specific verification procedures required by a carbon market will likely depend on the market; this protocol will focus on QA/QC measures that will be important regardless of end use for the data. Additional measures may be necessary depending on the carbon market.

A QA/QC plan should be developed and documented for the project. Elements of the plan include data quality objectives, QA/QC activities (includes data collection, recording, entry into database, data analysis, database management, laboratory procedures, etc.), roles and responsibilities, timelines, what to do if errors are found, documentation procedures, data management/archival etc. The plan and documentation of QA/QC activities should be kept in a project QA/QC notebook. Some examples of plan elements are provided below:

- Data quality objectives. Examples may include:
    - Timeliness
    - Completeness
    - Consistency (internal and time series)
    - Accuracy
    - Transparency

- List of QC activities, each includes:
    - Roles and responsibilities
    - Timeline
    - Course of action if errors are found
    - Documentation

Example QC activity: Check for completeness, accuracy, and legibility on datasheets. To be completed by the datasheet recorder or another crew member every day before leaving field plot. Small errors to be corrected by recorder; recorder to ask surveyor if more information is needed, re-measurements may be necessary. Issues in data collection (i.e., incorrect data measurements) should be brought to the attention of surveyors and/or the field supervisor; corrective action should be taken (i.e., reviewing field protocol and re-training of crew members) if needed. QC activities should be documented on the datasheet including name of person completing the QC, the date, and notes on errors found and corrective actions taken.

- List of QA review procedures, each includes:
    - Roles and responsibilities
    - Timeline
    - Course of action if errors are found
    - Documentation

Example QA procedure: Review 10% of datasheets for completeness, accuracy, and legibility. To be completed by (name entity) half-way through data collection and at the end of data collection (more often if significant problems are noted). All issues should be brought to the attention of the field supervisor and corrected on both the datasheet and the electronic database. Issues that require broader action should be dealt with as soon as possible (i.e., incorrect field measurements may require re-training and/or re-measurement). QA procedure, including name of reviewer, date of review, issues/errors found, and corrective actions taken, should be documented on the (name) form and filed in the project QA/QC notebook.

- Data management/archival, each includes:
    - Roles and responsibilities
    - Timeline
    - Data security
    - Documentation

Example: Data management/archival activity: Managing electronic database(s). Once data is entered into an electronic database and reviewed by person entering the data, a read-only copy will be made with the date of the update in the filename. New data will be entered into the original non-read-only copy. The final read-only copy will have the date and “final” in the filename. Analysis should take place on a separate copy of the database that is not read-only. Documentation including filenames, name of database manager, date file created/altered, and notes should be on the form and filed in the project QA/QC notebook. Finally, all original hard-copy datasheets should be kept on file for future reference. A xeroxed hard-copy set of the datasheets should also be kept in an alternate locale.

Sample QA/QC forms are provided in the datasheet file. These should be adapted to meet the specifics of the QA/QC plan developed for the project.

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Appendix A. Table of species codes for trees.

Common Name	Scientific Name	Species Code
Amur	*Amoora cucullata*	AMCU
Babul	*Acacia nilotica*	ACNI
Baen	*Avicennia officinalis*	AVOF
Ban Jam	*Eugenia fruticosa*	EUFR
Batla/Batul	*Excoecaria indica*	EXIN
Bhaela/Baral	*Intsia hijuga*	INHI
Bhola	*Hibiscus tiliaceus*	HITI
Bon Lichu	*Lepisanthes rubiginosa*	LERU
Bon Notoy	*Mallotus repandus*	MARE
Choyla/Ora/Soyla	*Sonneratia caseolaris*	SOCA
Dhundul	*Xylocarpus granatum*	XYGR
Doyal	*Mucuna gigantea*	MUGI
Gab	*Diospyros peregrina*	DIPE
Garjan/Jhanna	*Rhizophora mucronata*	RHMU
Gewa	*Excoecaria agallocha*	EXAG
Goran	*Ceriops decandra*	CEDE
Jhao	*Tamarix indica*	TAIN
Jir	*Ficus sp*	FISP
Kankra	*Bruguiera gymnorhiza*	BRGY
Karanj/Karanja	*Pongamia pinnata*	POPI
Keora	*Sonneratia apetala*	SOAP
Khalisha/Khalshi/Khulsha	*Aegiceras corniculatum*	AECO
Kirpa/Kripa	*Lumnitzera racemosa*	LURA
Passur	*Xylocarpus mekongensis*	XYME
Sadda Baen/White Baen	*Avicennia alba*	AVAL
Shingra	*Cynometra ramiflora*	CYRA
Sitka/Sitki	*Clerodendrum inerme*	CLIN
Sundri	*Heritiera fomes*	HEFO
Sundri Iota	*Brownlowia tersa*	BRTE
Unknown species		UNSP

Appendix 2. Table of allometric equations for computing biomass.

Species group	Equation	Source	Data origin	Max input
Mangrove Tree (dbh-density-ht)	$B = 0.0509*\rho*(dbh)^2 *ht$	Chave et al. (2005)	Asia, Americas, Australia	50 cm dbh
Mangrove Tree (dbh-density)	$B = \rho * \exp[-1.349 + 1.980*\ln(dbh) + 0.207*(\ln(dbh))^2 - 0.0281*(\ln(dbh))^3]$	Chave et al. (2005)	Asia, Americas, Australia	50 cm dbh
Mangrove Tree (dbh-density)	$B = 0.168*\rho*(dbh)^{2.46}$	Komiyama et al. (2008)	Asia, Australia	49 cm dbh
Palms (*asai* and *pataju*)	$B = 6.666 + 12.826*ht^{0.5} *\ln(ht)$	Pearson et al. (2005)	Central America	33 m ht
Palms (*motacu*)	$B = 23.487 + 41.851*(\ln(ht))^2$	Pearson et al. (2005)	Central America	11 m ht
Lianas	$B = dbh^{2.657} * e^{-0.968}$	Schnitzer et al. (2006)	Asia, Americas	23 cm dbh
Belowground Tree Biomass	$BBD = \exp(-1.0587 + 0.8836*\ln(ABD))$	Cairns et al. (1997)	Asia, Americas, Europe	982 Mg ha^{-1}

B = biomass (kg), ht = height (m), dbh = diameter at breast height (cm), ρ = wood density (g cm^{-3}), BBD = belowground biomass density (Mg ha^{-1}), ABD = aboveground biomass density (Mg ha^{-1}).

ANNEX V: GROUP WISE PARTICIPANT LIST

Certificate Training Course on Carbon Financing Project Preparation

Fisheries Training Academy, Savar

October 28 – November 11, 2009

Group # 1

Sl.	Name	Designation	Department
01	Imran Ahmed	Assistant Conservator of Forests	FD
02	Md. Abdur Rahman	Assistant Conservator of Forests	FD
03	Md. Oli Ul Haque	Assistant Conservator of Forests	FD
04	Mostafizar Rahman	Assistant Conservator of Forests	FD
05	Md. Saidur Rahman	Assistant Director	DOE
06	Profulla Kumar Sarker	District Fisheries Officer	DOF
07	Tapan Kumar Paul	Assistant Director	DOF
08	Abdur Rouf	Senior Upazila Fisheries officer	DOF

Group # 2

Sl.	Name	Designation	Department
01	Md. Towfiqul Islam	Assistant Conservator of Forests	FD
02	Md. Subedar Islam	Assistant Conservator of Forests	FD
03	Md. Rakibul Hasan Mukul	Divisional Forest Officer	FD
04	Md. Abdul Awal Sarker	Divisional Forest Officer	FD
05	ANM Azizul Islam Khan	Upazila Fisheries officer	DOF
06	Monish Kumar Mondol	Senior Upazila Fisheries officer	DOF
07	Farid Ahmed	Deputy Director	DOE
08	Md. Abul Kalam Azad	Analyst	DOE

Group # 3

Sl.	Name	Designation	Department
01	Md. Mozaharul Islam	Assistant Chief Conservator of Forests	FD
02	Abu Naser Md. Yasin Newaz	Divisional Forest Officer	FD
03	Md. Zaheer Iqbal	Deputy Conservator of Forests	FD
04	Md. Zahid Hossain	Senior Upazila Fisheries officer	DOF
05	Md. Wahiduzzaman	Senior Upazila Fisheries officer	DOF
06	Md. Sadiqul Islam	Analyst	DOE
07	Md. Hassan Habibur Rahman	Research Officer	DOE