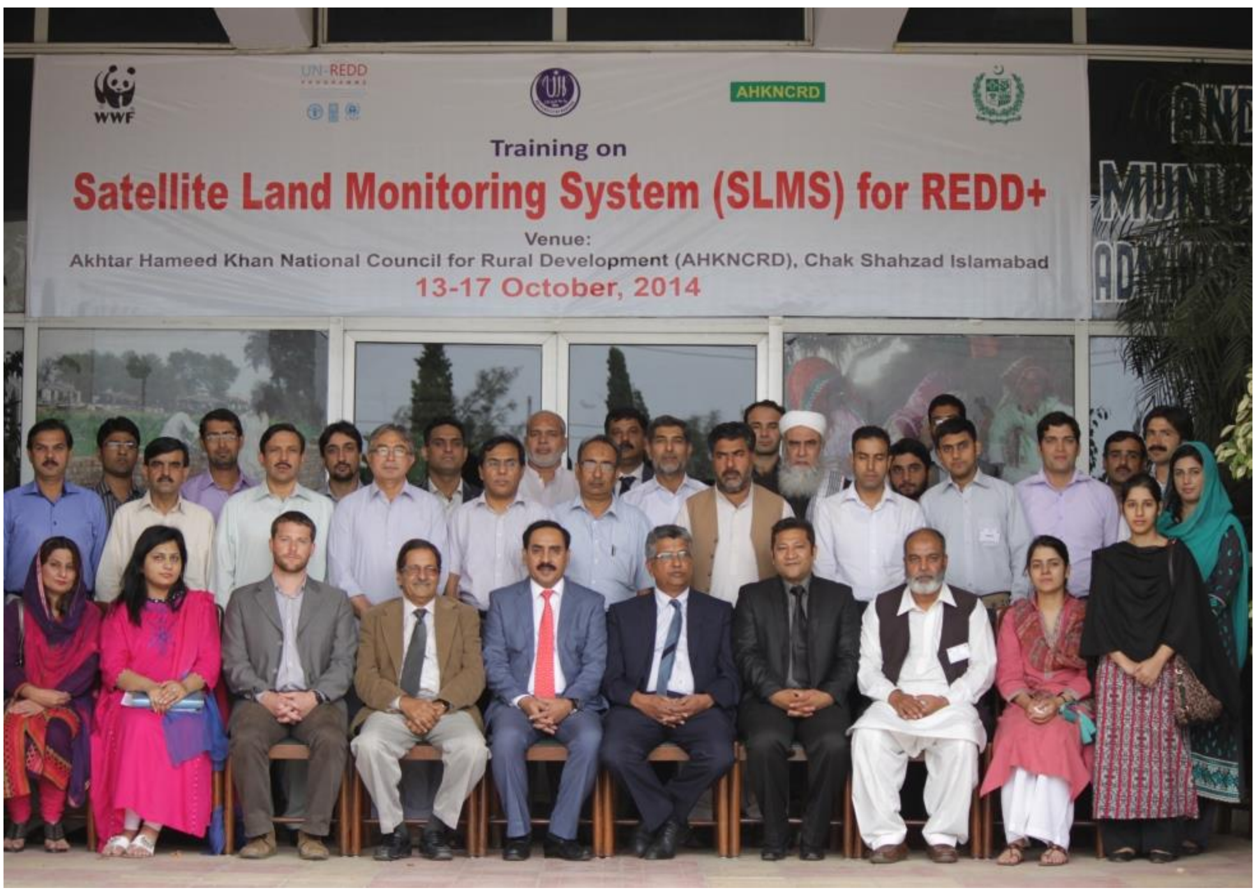
Report of the Training on the Satellite Land Monitoring System (SLMS) for REDD+

13-17th October 2014

at

AHKNCRD, Islamabad



Reducing Emissions from Deforestation and Forest Degradation (REDD+) Project: "Preparation of Action Plan and Capacity Building for a National Forest Monitoring System (NFMS)"

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Background and Objectives

Pakistan joined UN-REDD as a partner in 2011 and is set to operationalize and mainstream REDD+ in its forest management practices. Following this, Pakistan has initiated REDD+ activities in the country and potential REDD+ demonstration sites for the future have also been identified (MoE, 2012). The inputs acquired through this process are being utilized to develop the REDD+ National Strategy and Implementation Plan. In July, 2013 Pakistan also became a member of Forest Carbon Partnership Facility (FCPF) and submitted its REDD+ Readiness Preparation Proposal (RPP) to FCPF in November, 2014 and secured USD 3.4 million from its readiness fund for next five years.

Presently a project titled “Preparation of Action Plan and Capacity Building for a National Forest Monitoring System (NFMS) for REDD+” is being implemented by WWF-Pakistan under the overall supervision and guidance of the OIGF to take the REDD+ preparation further and help Pakistan to develop a robust National Forest Monitoring System. The UN-REDD Program is providing both financial and technical support under its Target Support Fund. The project has two outputs i.e. 1) development of the NFMS Action Plan and 2) development of capacities of stakeholders for forest monitoring, Greenhouse Gas Inventory (GHG-I) and overall implementation of NFMS Action Plan. Under its output-1 the project intends to conduct 1) detailed mapping of existing NFMS capacity, gaps and needs of both national and provincial forest administrations and other relevant government organizations, 2) developing standard methodology for spatial analysis of forest cover change, 3) assessment of data availability for LULUCF GHG inventory and 4) develop draft NFMS action plan.

The purpose of this training was to introduce the concept of Satellite Land Monitoring System and provide some hands-on sessions to the Open Foris Initative tools developed within FAO (CollectEarth and Geospatial Toolkit) so as to help WWF draft the SLMS design and related work plan.

Training Participants and Agenda

35 people from provincial forest departments, spatial agency, urban unit, academia and non-government organizations (NGOs) attended the 4.5 days workshop with introductions and hands on sessions on Collect Earth and Geospatial Toolkit from the Open Foris suite. In addition, a presentation of the NFMS portal that UN-REDD FAO developed in DR Congo, Paraguay and Zambia were given by the RO. Diverse presentations on IPCC requirements for NFMS, REL/RLs, field data collection and Lidar experience in Nepal were given by two experts from WWF-Nepal (Ugan Manandhar) and Arbonaut (Basanta Gautam) during the week. The detailed agenda is attached as Annex I.

Organizers and Facilitators

The training on Satellite Land Monitoring System (SLMS) for Pakistan was co-organised by WWF-Pakistan and the Climate Change Division with financial support from the Targetted Support (TS) fund of UN-REDD and took place at the Akhtar Hameed Khan National Centre for Rural Development (AHKNCRD).

The overall training was facilitated by the International Expert Mr. Remi D'ANNUNZIO and co-facilitated by two experts from WWF-Nepal (Ugan Manandhar) and Arbonaut (Basanta Gautam). WWF-Pakistan team included Mr. Muhammad Ibrahim Khan and Mr. Muhammad Afrasiyab provided the overall support.

Proceedings of the Training

Inaugural Session

Syed Mahmood Nasir welcomed all the participants and also avowed the leading resource persons of the training. Formally the training started with the recitation of the Holy Quran followed by the introduction of the participants. After that Mr. Muhammad Ibrahim Khan, Senior Manager Conservation, WWF-P officially welcomed all the participants and also thanked the international resource persons Mr. Remi DAnnunzio and Mr. Ugan Manandhar for coming to Pakistan and guiding the SLMS process. He also appreciated the efforts of Mr. Mahmood Nasir, Inspector General Forest, National Focal Person REDD+.

Figure 1: Opening remarks by Syed Mahmood Nasir, IGF

Inspector General of Forests, and National Focal Point REDD+, Syed Mahmood Nasir, opened the session insisting on the need to stick to UNFCCC and IPCC recommendations for the setting up of NFMS in Pakistan.

Figure 2: Presentation by Mr. Abdul Rauf Qureshi

The first presentation was delivered by Mr. Abdul Rauf Qurreshi on NFMS as the 4th component of Pakistan Readiness Preparation Proposal (RPP). He briefed about the decisions related to NFMS for REDD+ in the COP's and their status of implementation in Pakistan. He referred to decisions of COP 15 and 16 including methodological guidance provided by IPCC and phased approach under national circumstances. He described the importance of a central repository of all information about REDD+.

Mr. Abdul Rauf Qureshi explained the objectives of NFMS:

- Monitoring of emission and removal of GHG during REDD+ activities,
- How safeguards are addressed
- To provide implementation support for enabling Elements of M&MRV and additional functions.

He also briefed about the three pillars on which a robust transparent NFMS can be developed. They includes

- Satellite Land Monitoring System (SLMS) for data about the forest land
- National Forest Inventory (NFI) for Information about forest carbon stock and changes
- National GHG Inventory, for reporting on anthropogenic GHG emissions and removals related with forest

Mr. Abdul Rauf Qureshi explained that NFMS covers monitoring of all managed forest lands including Range Lands, tree grooves, fruit trees, agroforestry and linear plantations. He also described the existing capacities and institutional arrangements of Pakistan and emphasizes on the importance of its quick and accurate assessment for implementing REDD+ activities.

The second presentation was conveyed by Ms. Sana Elyas, on behalf of Syed Mahmood Nasir, IGF, in which she enlightened the participants on the important decisions of different Conference of Parties pertinent to MRV, FRL/FREL and NFMS. She identified that the developing countries, for the sake of MRV have to:

- Identify Drivers of Deforestation and means to address these;
- Identify activities that reduce emissions and increase removals
- Use IPCC guidance /guidelines for estimating GHG emissions / removals
- Establish, according to national circumstances and capabilities, robust and transparent NFMS (if appropriate, sub-national systems)

Figure 3: Ms. Sana Elyas delivering her presentation

During the presentation Mr. Syed Mahmood Nasir, IGF asked the participants about the difference between Reference Emission Levels (REL's) and Reference Levels (RL's). Mr. Muhammad Ibrahim Khan and Mr. Abdul Rauf Qureshi differentiated both terminologies and were further supported by Mr. Ugan Manandhar and Mr. Remi D Annunzio. It was clear after a discussion that the Forest Reference Emissions Level (FREL) deals only with the gross emissions in forest cover change whereas FRL deals with the net emissions as well as removals involved in the "+" of REDD+.

Later, Mr. Remi DAnnunzio and Mr. Ugan gave a brief overview of the SLMS training objectives and program. Their detailed presentations are contained in Annexes III (a) & (b).

At the end of the inaugural session Mr. Zafar Qadir, Director General, Akhtar Hameed Khan National Center for Rural Development (AHKNCRD) showed his pleasure on the interests participants displayed in understanding the new concepts and technologies of REDD+. He announced that the premises of AHKNCRD is planned to be declared as REDD+ academy for the region. He hoped that the REDD+ trainings of young professional would continue in future.

Figure 4 Remi D'Annunzio Introducing new tools of SLMS

Figure 5 Ugan Manandhar delivering his presentation on International Negotiations on REDD+

Training Sessions

Use of FOSS tools

Tools introduced during the workshop are Free and Open Source Softwares, officially released at the XIV IUFRO congress (www.fao.org/news/story/en/item/254098/icode/).

Tools are available for download here www.openforis.org.

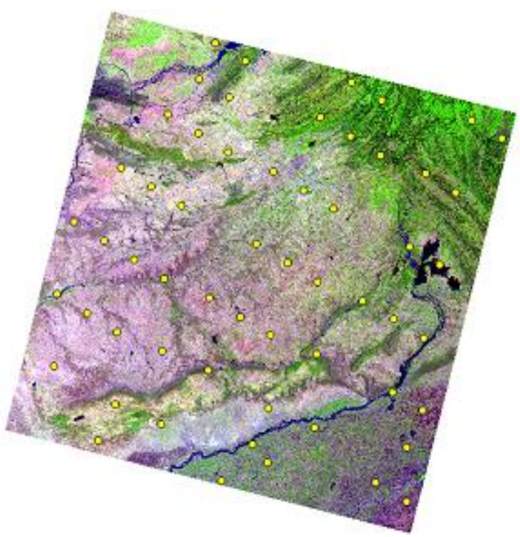
Collect Earth (http://www.openforis.org/tools/collect-earth/) is a tool that enables data collection through Google Earth. In conjunction with Google Earth, Bing Maps and Google Earth

Engine, users can analyze high and very high resolution satellite imagery for a wide variety of purposes, including:

- Support multi-phase National Forest Inventories
- Land Use, Land Use Change and Forestry (LULUCF) assessments
- Monitoring agricultural land and urban areas
- Validation of existing maps
- Collection of spatially explicit socio-economic data
- Quantifying deforestation, reforestation and desertification

Its user friendliness and smooth learning curve make it a perfect tool for performing fast, accurate and cost-effective assessments. It is highly customizable for the specific data collection needs and methodologies.

Collect Earth was used over one Landsat scene in Pakistan (Path 150 Row 037) with a systematic sampling using a basic IPCC classification scheme.



The FOSS for geographical system information software QGIS (www.qgis.org) was used with hands-on sessions to perform various image display (band combination, stretching, clipping and stacking imagery) and vector creation and manipulation exercises. In particular, the creation of systematic and random point grid was extensively examined.

The method to pass the created points into Collect Earth was presented a summary is available here: http://www.openforis.org/tools/collect-earth/tutorials/qgis.html.


Figure 6 Remi D'Anunzio helping the participants during practice sessions

The output of the Collect Earth exercise was used to generate training data, feeding an image classification process implemented with the Open Foris Geospatial Toolkit. (http://www.openforis.org/tools/geospatial-toolkit.html).

Open Foris Geospatial Toolkit is a collection of command-line utilities for processing of geographical data. It aims to simplify the complex process of transforming raw satellite imagery for automatic image processing to produce valuable information. It is particularly useful for processing big amounts of raster data, and provides a wide range of functionalities including image manipulation, statistics, segmentation and classification. The tools have been tested mainly in Ubuntu Linux environment and USB live sticks were prepared to work in this environment.


Figure 7 Participants during training

The processing chain was showed and handed over to the participants. It includes Unsupervised K-Means classification, Extraction of spectral signatures, Training of Random Forest algorithm and Change Detection between the same area of interest for a Landsat5 image of 1992 and a Landsat8 image of 2014.

Day to day program

Monday 13:

- Introductions to NFMS, IPCC, REL/RLs, Open Foris Initiative and tools

- Introduction to Collect Earth

Tuesday 14:

- Hands-on session with Collect Earth

- Demonstration of different features of CE (accuracy assessment, LULCF matrix)

- Presentation of NFMS web-portal

Wednesday 15:

- Hands-on session with QGIS

- Introduction to OFGT environment

Thursday 16:

- Hands-on session with OFGT

- Presentation of Lidar work in Nepal

Results

The laboratory of NCRD was equipped with computers but access to Internet was not stable enough to support access to Google Earth and no administrative rights were given with the machines so that OFGT could be tested (protection on the boot could not be removed by the administrator of the lab himself). The practical sessions hence occurred in a meeting room with participants' laptops and their own Internet mobile access. This also limited the use of OFGT as participants were not always keen to change the boot settings of their computers. In addition, the level of participants in GIS and RS was very heterogeneous, so exercises were kept simple and applied.

A presentation of the NFMS portal that UN-REDD FAO developed in DR Congo, Paraguay and Zambia were given.

Closing Session

The training formally ended on Friday 17th October 2014. Mr. Basanta Gautam delivered a conclusive presentation on Field Data Management using OpenForis Collect Mobile (OFCM) and ArboWebForest (AWF) technology. Mr. Ugan Manandhar also delivered his final presentation on Nepal ER-PIN- People and Forests; "An SMF Based Emission Reduction Program in the Terai Arc Landscape".

Figure 8 Mr. Basanta Gautam delivering his presentation on LIDAR based estimation of forest biomass

Figure 9 Mr. Ugan Manandhar delivering his presenation

Remarks by the Participants

In the end representatives from provincial forest departments shared their views about the training:

Mr. Sher Nawaz Khan, Conservator Forests FATA told that he felt much educated at the end of 5 days training. The part of training involving new tools and softwares of forest monitoring were found very helping but difficult to understand fully in the available time. He highlighted the need of future trainings on the same. He however showed his satisfaction that by using the guidance provided in the training his province can start working on the development of a National Forest Monitoring System.

Mr. Abdul Basit, Conservator Forests, Punjab expressed gratification over the opportunity provided to participate in the training. He ensured that what has learnt will be implemented in their province and other officers will be trained with the provided knowledge and guidance. He also suggested training process to be continued in the future to get more benefitted.

Mr. Fayyaz Ahmad, Divisional Forest Officer Sind also submitted that the training on the new tools of forest monitoring was very useful and beneficial. He told that Sind Province lacks in the human capacity for the data collection and RS/GIS operations in line with guidance of IPCC and UNFCCC. He expressed the need to seek the guidance of WWF-

Pakistan and Climate Change Division for understanding the technical aspects of the subject training in future.

Figure 10 Mr. Fayyaz (DFO) expressing his views on the training

Mr. Aslam Buzdar, Conservator Forests, Balochistan praised the role of Office of IGF and WWF-Pakistan in providing a beneficial training for implementing REDD+ in their province. He insisted on the continuity of such trainings to cope with the demands of the new era. He ensured that whatever is learned will be applied in the field.

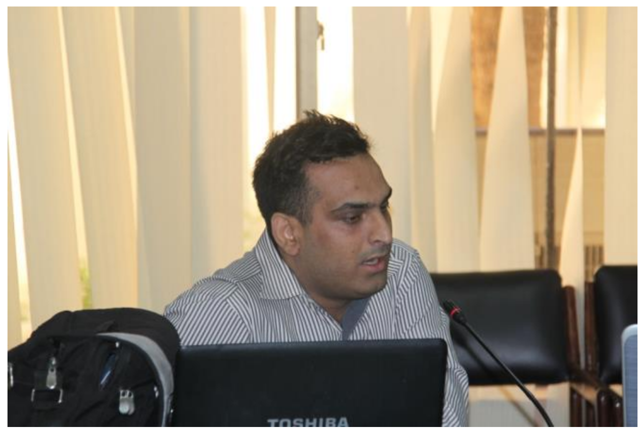


Figure 11 Mr. Ahmad Raza Chauhan with his views on the taining

Mr. Iftikhar, Divisonal Forest Officer, Azad Jammu and Kashmir (AJK) also expressed his satisfaction over the content of the training however he suggested that it would be more helpful if there could be more days allocated for the training. He told that his province also lack in the human capacity to have understanding on such kind of expertise. He showed great satisfaction over the deliverance of the three international resource persons during the training. The training parts were well communicated and clear in understanding.

Figure 12 Mr. Iftikhar DFO, expressing his views

Mr. Ahmad Raza expressed his views of the training. He said that the training was excellent and the international trainers were very relevant and informative. He gave suggestions to the representatives of the provincial forest departments to implement the knowledge gained and to show results for actual Reductions of Emissions from Deforestation and Forest Degradation in Pakistan.

Distribution of Training Certificates

Figure 12 Participant getting certificate of the training from the Chief guest

The certificates of the training were awarded to the participants of the training. Mr. Zafar Qadir, Director General, AHKNCRD, in his closing remarks, showed great pleasure in the kind of knowledge delivered during the training. He stressed on the importance of developing a system for computerized record of the national forest resources to precisely calculate the actual loss of the forest carbon. He thanked WWF-P and CCD for inviting him to the subject training as the chief guest.

Figure 14 Mr. Zafar Qadir with his closing remarks

Mr. Syed Mahmood Nasir, IGF, also thanked the participants and the international trainers for making the training useful. He welcomed the feedback of the participants' in developing a strategy for promoting REDD+ Academy for providing a permanent source of technical knowledge of REDD+. He showed full confidence over the acceptability of REDD+ project in Pakistan and insisted the participants to get fully prepared in the REDD+ Preparedness phase.

Annex I: Training Program/ Agenda

Day/ Time	Session	Topic	Resource person/ Chair
Day-1:			
9.00 am-9.30 am	1. Opening	Arrival and registration	WWF-Pakistan team
9.30 am-9.35 am		Recitation	One of the participants
9.35 am- 9.50 am		Welcome address	Syed Mahmood Nasir Inspector General Forests
9.50 am- 10.00 am		Introduction of the participants and their expectations	Lead resource person
10.00 am-10.15 am		Overview of Pakistan's progress on REDD+ Preparedness	CCD representative
10.15 am-10.30am		NFMS as the fourth Component of Pakistan RPP	Mr. Abdul Rauf Qureshi
10:30am – 10:45 am		SLMS training objectives and program	Lead resource person
10:45 am -11:00am		Address by the Chief Guest	Mr. Zafar Qadir, DG AHKNCRD
11.00 am - 11.15 am	Tea break		
End of Inaugural Session			
11.15 am – 11.30 am Chaired by Mr. Abdul Rauf Qureshi	2. Introduction to the SLMS	Brief overview of various methods and approaches (UNFCC/ IPCC recommended)	Ugan/Remi dAnnunzio
11.30 am – 1.00 pm	3. Understanding and using GIS/ RS Softwares for SLMS	Installation of the Software's+ Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
1.00 pm-2.00 pm	Lunch break		
2.00 pm – 4.00 pm		Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
4.00 pm-4.15 pm	Tea coffee break		
4-15pm-5:00pm		Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
Closing remarks by Mr. Abdul Rauf Qureshi			
Day-2:			
9.00 am - 11.00 am Chaired by Mr. Sher Nawaz Khan		Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
11.00 am - 11.15 am	Tea coffee break		

11.15 am - 1.00 pm		Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
1.00 pm-2.00 pm	Lunch break		
2.00 pm – 3.30 pm		Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
3.30 pm-3.45 pm	Tea coffee break		
3.45 pm 5.00 pm		Generate land use change transition matrix + gather training data (CollectEarth)	Remi dAnnunzio
Closing remarks by Mr. Sher Nawaz khan			
Day-3:			
9.00 am – 11.00 am Chaired by Mr. Aslam Buzdar		Introduction to OpenForis Geospatial Toolkit environment +web portal	Remi dAnnunzio
11.00 am – 11.15 am	Tea coffee break		
11:15am – 1:00pm		Introduction to OpenForis Geospatial Toolkit environment +web portal	Remi dAnnunzio
1.0 pm-2.00 pm	Lunch break		
2.00 pm – 3.30 pm		Image processing + unsupervised classification	Ugan/Remi dAnnunzio
3:30pm-3.45pm	Tea coffee break		
3.45pm-5.00pm		Image processing + unsupervised classification	Ugan/Remi dAnnunzio
Closing remarks by Mr. Aslam Buzdar			
Day-4:			
9.00 am – 11.00 am Chaired by Mr. Abdul Basit		Supervised classification chains + statistics generation	Ugan/Remi dAnnunzio
11.00 am – 11.15 am	Tea coffee break		
11.15am-1:00pm		Supervised classification chains + statistics generation	Ugan/Remi dAnnunzio
1.00 pm-2.00 pm	Lunch break		
2.00Pm-3.30 pm		Short Presentations on Status of Forest Monitoring System in Provinces for REDD+ (Requirements and gaps)+ A plenary discussion on harmonization of Satellite data requirements and needs for SLMS	Mr. Kamran Hussain+ Provincial focal points + Remi dAnnunzio/ Ugan
		Wrap-up and follow up steps	

3.30 pm – 3.45 pm	Tea coffee break		
3.45Pm-5.00Pm		Estimation of forest biomass using LiDAR-Assisted Multisource Programme	Mr. Basanta Gautam
Closing Remarks by Mr. Abdul Basit			
Day-5:			
09.00am – 10.45 am		Field data management: OpenForis Collect Mobile (OFCM) and ArboWebForest (AWF) technology	Mr. Basanta Gautam
10.45 am – 11.00 am		Nepal ER-PIN- People and Forests An SMF Based Emission Reduction Program in the Terai Arc Landscape	Mr. Ugan
11.00am-11.15 am	Tea coffee		
11.15 – 12:00 am		Closing Remarks & Certificates Distribution	IGF/ Secretary Environment
12.00 pm- 1.30 pm	Lunch and prayer		
1.30 pm – 2.30 pm Lunch	Closing	Closing	

Annex II: Attendance Sheets 13-17 October 2014

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WORKSHOP SIGN-IN SHEET

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15-Oct-2014
SIMS TRAINING
DAY 3

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15-oct-2014

SLMS TRAINING
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16/oct/2014
SLMS TRAINING

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16/oct/2014
SLMS Training

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11	Fayyaz Aslam	Deputy Director	AHK NCRD			
12	Basit Ali	Ph.D Scholar	PMAS-AAUR	0321 5071085	bbasitali@gmail.com	Basit Ali
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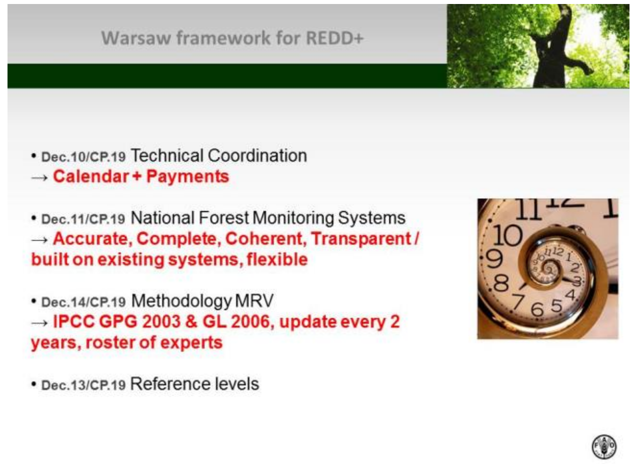
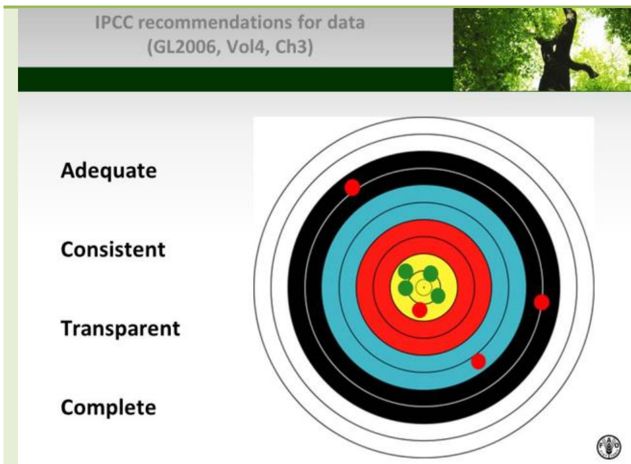
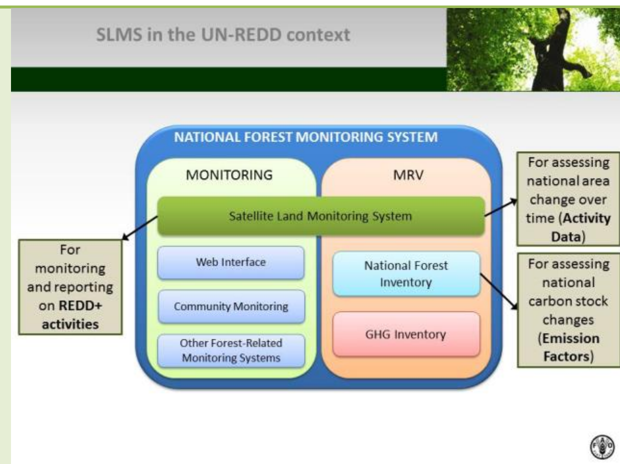
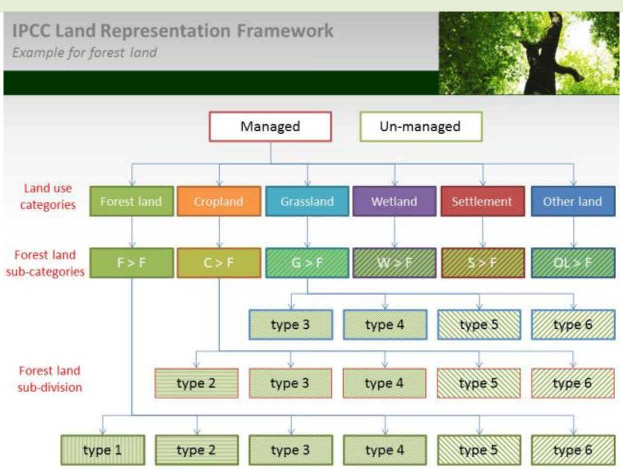
Annex III (a)

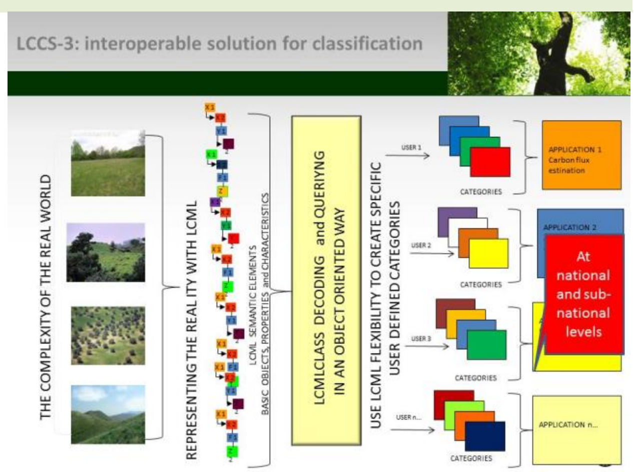
Presentations by Mr. Remi D'Annunzio

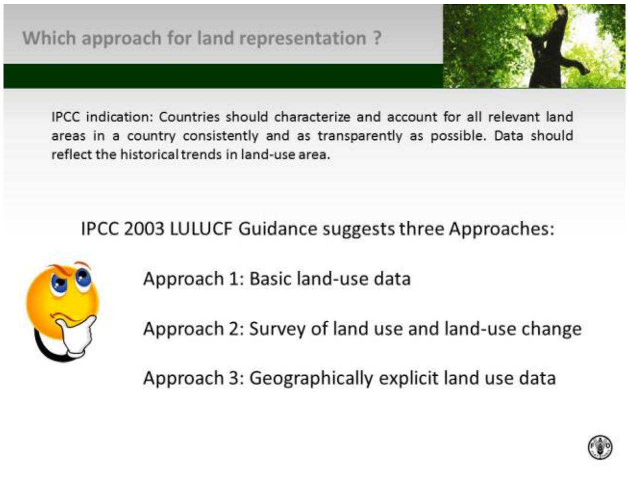




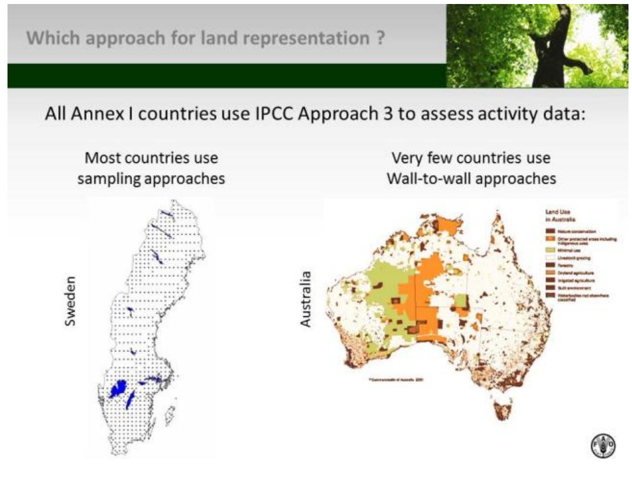




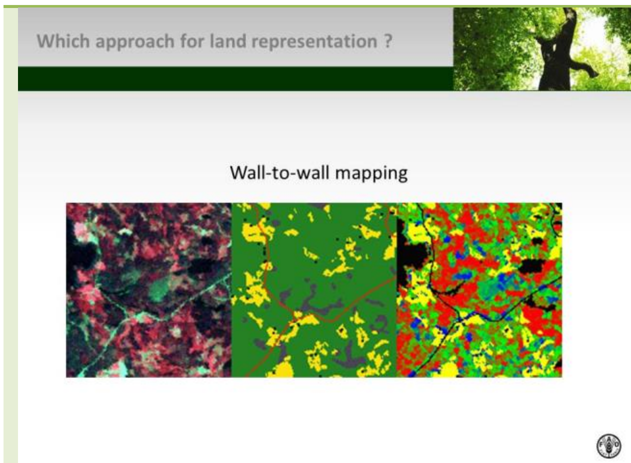




Which approach for land representation ?
IPCC indication: Countries should characterize and account for all relevant land areas in a country consistently and as transparently as possible. Data should reflect the historical trends in land-use area.
IPCC 2003 LULUCF Guidance suggests three Approaches:
Approach 1: Basic land-use data
Approach 2: Survey of land use and land-use change
Approach 3: Geographically explicit land use data



Which approach for land representation ?
All Annex I countries use IPCC Approach 3 to assess activity data:
Most countries use sampling approaches
Very few countries use Wall-to-wall approaches
Sweden
Australia



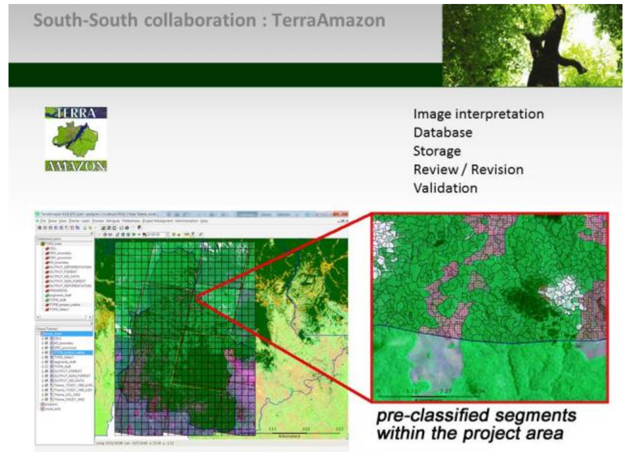
Which approach for land representation ?
Wall-to-wall mapping

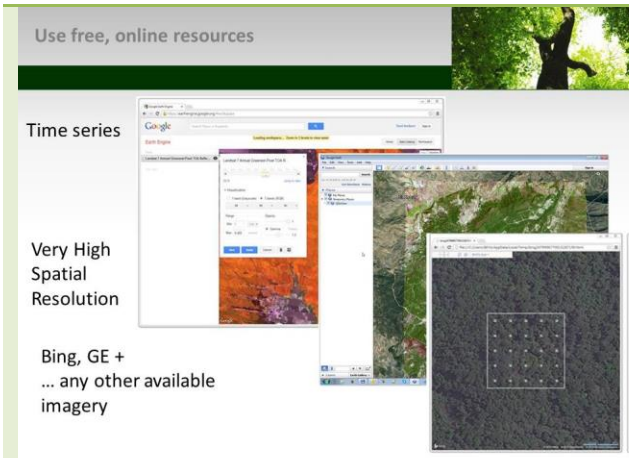
Open Foris Initiative
www.openforis.org
openforis
Free open-source solutions for forest monitoring
Collect
Collect Earth
Calc
Collect Mobile
Geospatial Toolkit

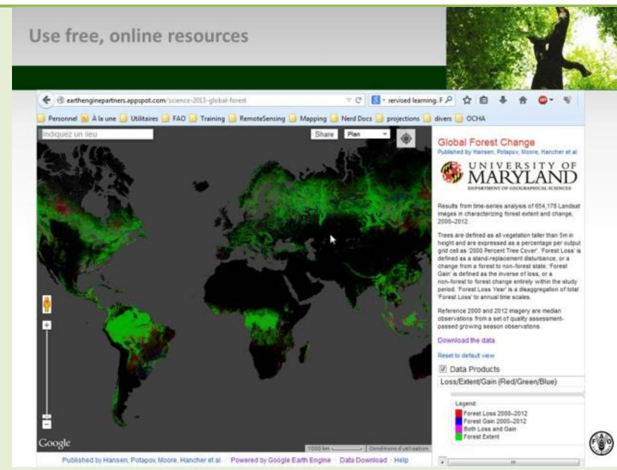
Open Foris Initiative: Collect Earth
Java
openforis
Google earth engine
Google fusion tables
bing maps
saiku
PostgreSQL
SQLite
COLLECT EARTH
Collect Earth
Land use dynamics
F to F
F to NF
NF to NF
NF to F
Accuracy
High
Medium
Low
Year of change

Open Foris Geospatial Toolkit
http://km.fao.org/OFwiki/index.php/Tools_%26_Exercises
OPENFORIS
GEOSPATIAL TOOLKIT
See also


OFGT : a set of FOSS utilities
ubuntu
linux for human beings
www.ubuntu-fr.org
GDAL
www.gdal.org
www.r-project.org
OSGeo
Your Open Source Compass
www.osgeo.org

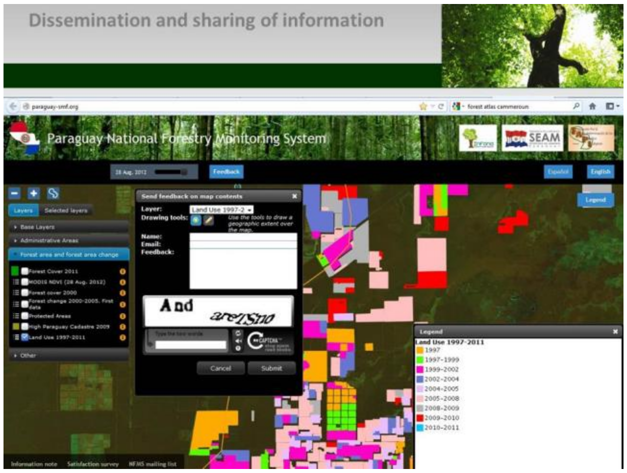

South-South collaboration : TerraAmazon
TERRA
AMAZON
Image interpretation
Database
Storage
Review / Revision
Validation
pre-classified segments
within the project area

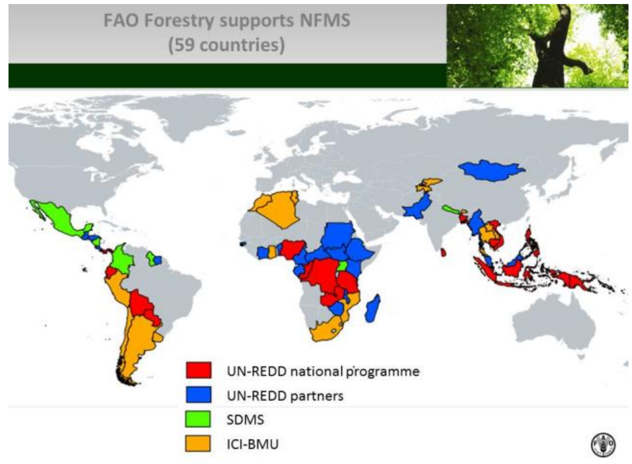

Use free, online resources
Time series
Very High
Spatial
Resolution
Bing, GE +
… any other available
imagery


Use free, online resources
Global Forest Change
UNIVERSITY OF
MARYLAND
Google


Use free, online resources
https://ee-api.appspot.com/
Pakistan


Acquire Very High Resolution
15 $ / km2

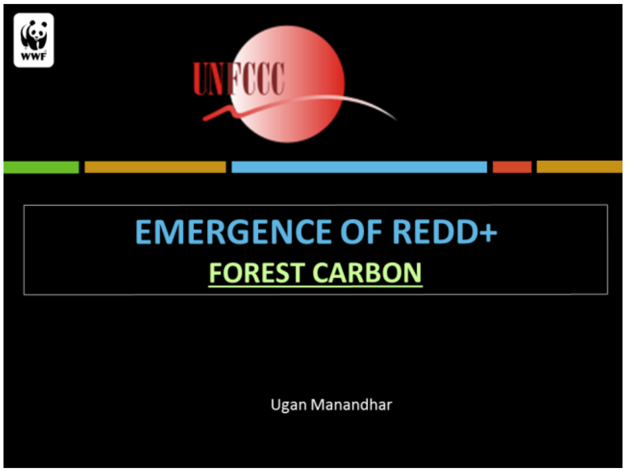

Dissemination and sharing of information
Paraguay National Forestry Monitoring System
SEAM
Send feedback on map contents
Cancel
Submit
Legend
Land Use 1997-2011

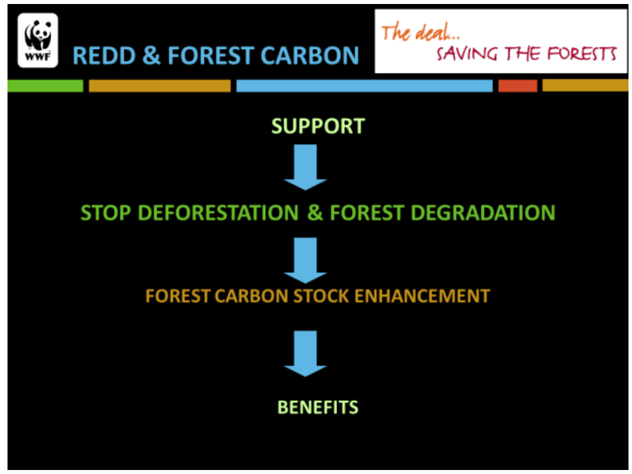

FAO Forestry supports NFMS
(59 countries)
UN-REDD national programme
UN-REDD partners
SDMS
ICI-BMU

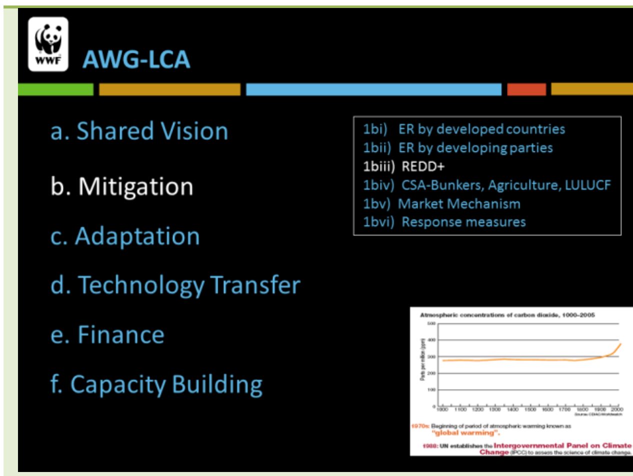

شكريه
Thank you

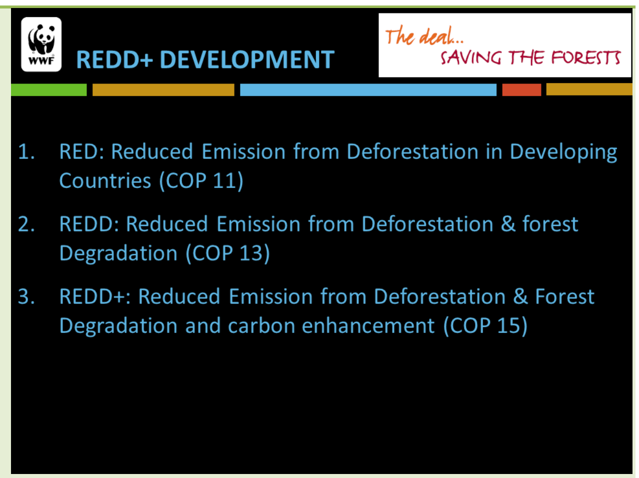
Annex III (b)

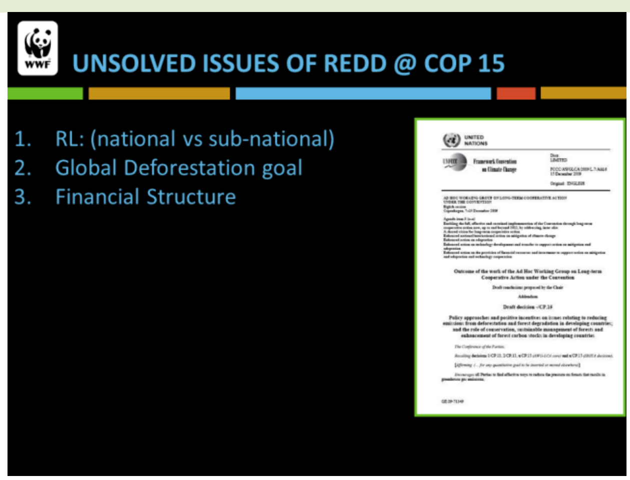
Presentations delivered by Mr. Ugan Manandhar











REDD+ RL

Sub-National Jurisdictional RL
in the
Terai Arc Landscape

WHAT IS RL/REL

Forest Reference Emission Levels &/or Forest Reference levels:

- Benchmarks for assessing a country's performance in implementing REDD+ activities
- Expressed in tons of CO_2 eq/ year
- Credible ones will be driven by historical data: any projections (while allowed) will receive substantial more scrutiny and criticism

Benchmarks:

- Moving from **REDD+ readiness – Demonstration- Performance Based Payments**.

CONTEXT

- COP 17 invited Parties to submit subnational/ national RL
- COP 19 provided guidelines for technical assessment
- Science and methodologies for RL evolving
- Significant challenges in achieving the accuracy and integrity
- Data & National frameworks for RL/MRV in Nepal being developed
- RLs will not be perfect but expect us to use best available data & methods

REL/RL: MODALITIES & GUIDELINES: 12/CP17

Modalities

a. REL/RL expressed in **CO_2 eq**
b. Voluntary submission
c. A step wise approach to be take to improve RL/REL
d. A **sub-national approach as an interim** transitioning to a national RL/REL
e. Should be **updated** based on new knowledge, trends & modification of scope & methodologies
f. REL/RL should be made available in the Web Plat form

REL/RL: MODALITIES & GUIDELINES: 12/CP17

Guidelines for submissions:

a. Transparent, comprehensive, consistent and accurate including historical data
b. Pools & gases and activities listed in 1/CP16 & reasons for not choosing
c. Definition of forests

REL/RL: TECHNICAL ASSESSMENT: XX/CP19

a. Look into **consistency, completeness, transparency & accuracy**
b. How **historical data** have been taken into account
c. Whether **relevant polices** and plans have been referred to
d. Pools and gases and activities reported & why dropped if any
e. The **definition of forest** used
f. No judgments of policies
g. CB needs to be identified

REL/RL: TECHNICAL ASSESSMENT: XX/CP19

h. Technical assessment of RL/REL : UNFCCC **LULUCF experts**.

i. Assessment will be done by **1 developing and 1 developed country**

j. Assessments once a year & submission is **10 weeks prior to Bonn session**

k. The assessments can be shared in the session or if revised in web platform

BASIS OF REDD+ RL

The basic math is:

Activity Data (ha loss or ha gained/per year)

X

Emissions Factors (tCO_2e/ha)

=

$tCO_2e/year$

- Activity data: >>satellite information (past) / assumptions (future)
- Emission factors: >>field measurements & Allometric equations
  >> net changes in forest carbon between the classes Used in the activity data

AREA

APPROACH

Approach: Historical RL @ sub-national scale

- Base Year 1999
- Project Area; 12 jurisdictional boundaries

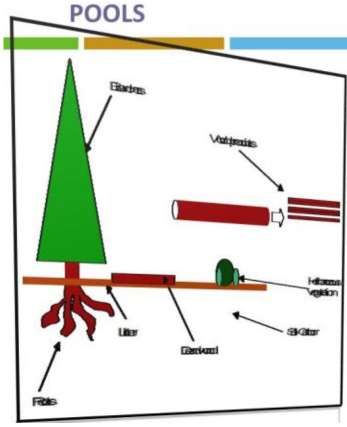
Tools: Img Tools (NDFI) & LiDAR (Arbo-LiDAR & LAMP)

- Generate activity data (AGC) (1999 to 2011)
- Emissions factors derived from plot data
- Larger plots for calibration of LiDAR

Allometric Equations

- Chave et all, Moist Forest- Diameter Model- (Eq: 1.3)
- Sharma and Pukkala

POOLS



Above Ground Biomass

Below Ground Biomass

Shrubs

Litter

Soil Organic Carbon

RECENT DEVELOPMENT

- Breakthrough in relating LiDAR measurements directly to AGC
- Relation between NDFI:AGC is weak
- NDFI/Imagine Tool useful in delineating intact & degraded forests
- Draft FCPF Methodological Framework circulated from the CF
- CAMCO and Agri-Consult to ensure TAL RL consistent with national framework for RL and MRV
- Process of availability of new government data

EVOLUTION OF LAMP

2009
- FCD Mapper

2010
- Forest Carbon Inventory

2011
- Arbonaut/FRA/WWF LiDAR campaign
- 738 field plots
- Initial LAMP modeling (weak correlation to AGC)

EVOLUTION OF LAMP

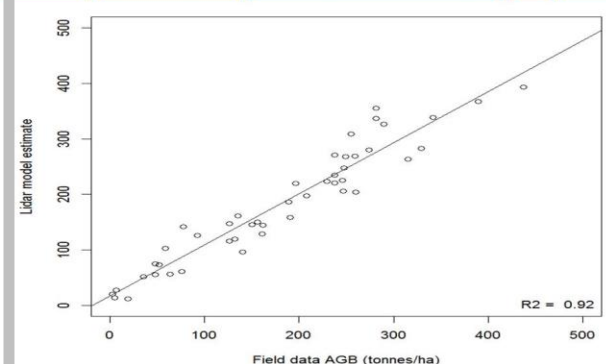
2012
- FCD Mapper Landsat analysis (weak correlation to AGC)
- First LiDAR-based biomass maps and Kathmandu training session
- Continued refinement of methodology
- Use of NDFI
- Consultations with government on forest classes
- Review of draft RL; Weak correlation with AGC and NDFI
- Initiation of ER-PIN process
- FRA underway to revise forest data

2013
- NDFI Landsat analysis : good delineation of degradation but weak correlation to AGC)
- Extensive external and internal technical review
- 48 larger field plots (30-meter radius)
- New LAMP modeling with larger plots (very strong 0.92 correlation)
- Development of LAMP Tier 2 and LAMP Tier 3 approach
- New preliminary FRA data

LAMP APPROACH

- The current effort : Tier 2 level LAMP estimate of biomass
- Tier 2 LAMP is based on:
  - Stratification of forest to 4 forest types,
  - Each with 'intact' and 'degraded' parts,
  - average biomass/ha obtained from LiDAR/Ground plots
- The Tier 2 Approach: combine the best data & results from both the LiDAR & land-cover change analysis
- Aim: Approach Tier III

AGC AND LiDAR CORRELATION



ANALYSIS

Total Area Forest Area: 4,268, 798 Ha (2005)

12 District Forest Ares: 842,755 Ha: 19.75%
939,525 Ha: 22.0%

ANALYSIS

4 Classes: Sal
Sal Mixed
Other Mixed
Riverine

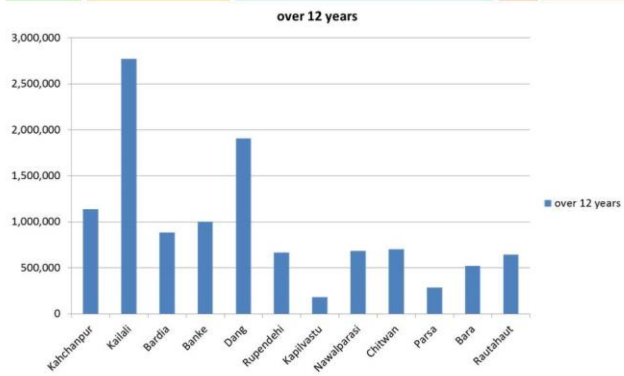
Activity:

Intact to Deforested	Deforestation 1
Degraded to Deforested	Deforestation 2
Regenerated to Deforested	Deforestation 3
Intact to Degraded	Degradation
Deforested to intact/degraded	Regeneration
Degraded to Intact	Enhancement

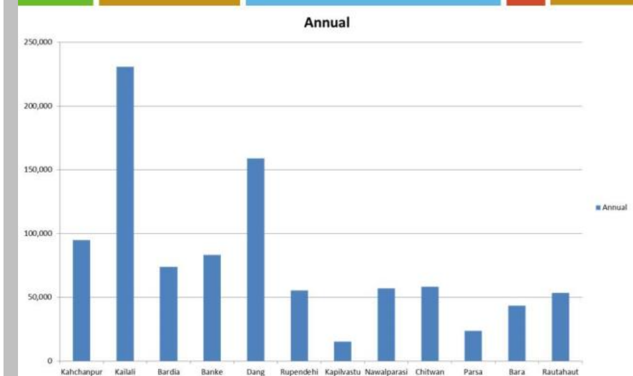
ANALYSIS

Forest Type	Transition	Activity	Factor tC/ha
Sal Forest	Intact to Deforested	Deforestation 1	110.7
	Degraded to Deforested	Deforestation 2	81.4
	Regenerated to Deforested	Deforestation 3	6.0
	Intact to Degraded	Degradation	29.3
	Deforested to intact/degraded	Regeneration	-6.0
	Degraded to Intact	Enhancement	-6.0
Sal Mixed	Intact to Deforested	Deforestation 1	86.1
	Degraded to Deforested	Deforestation 2	68.8
	Regenerated to Deforested	Deforestation 3	6.0
	Intact to Degraded	Degradation	17.3
	Deforested to intact/degraded	Regeneration	-6.0
	Degraded to Intact	Enhancement	-6.0
Other Mixed	Intact to Deforested	Deforestation 1	87.5
	Degraded to Deforested	Deforestation 2	67.3
	Regenerated to Deforested	Deforestation 3	6.0
	Intact to Degraded	Degradation	20.2
	Deforested to intact/degraded	Regeneration	-6.0
	Degraded to Intact	Enhancement	-6.0
Riverine	Intact to Deforested	Deforestation 1	80.4
	Degraded to Deforested	Deforestation 2	46.7
	Regenerated to Deforested	Deforestation 3	6.0
	Intact to Degraded	Degradation	33.7
	Deforested to intact/degraded	Regeneration	-6.0
	Degraded to Intact	Enhancement	-6.0

ANALYSIS



ANALYSIS

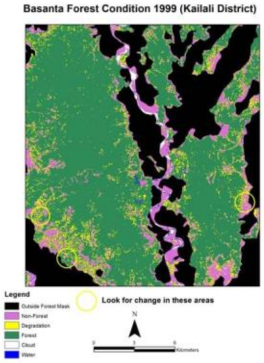


ANALYSIS

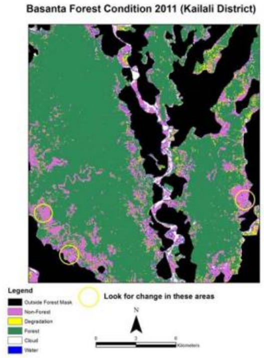
	Emission(tC)		tCO2 Emission	Reduce tCO2	Annual Payment	Total Payments
District	over 12 years	Annual	per year	by 50%	at $7/tCO2	for 5 years
Kahchanpur	1,138,952	94,913	348,013	174,006	1,218,045	6,090,227
Kailali	2,771,060	230,922	846,713	423,356	2,963,494	14,817,472
Bardia	885,184	73,765	270,473	135,236	946,655	4,733,275
Banke	999,443	83,287	305,385	152,693	1,068,849	5,344,243
Dang	1,907,885	158,990	582,965	291,482	2,040,377	10,201,884
Rupendehi	664,494	55,375	203,040	101,520	710,640	3,553,199
Kapilvastu	182,432	15,203	55,743	27,871	195,100	975,502
Nawalparasi	684,735	57,061	209,225	104,612	732,286	3,661,429
Chitwan	700,413	58,368	214,015	107,008	749,053	3,745,264
Parsa	286,268	23,856	87,471	43,735	306,147	1,530,737
Bara	519,557	43,296	158,753	79,377	555,637	2,778,185
Rautahaut	641,951	53,496	196,152	98,076	686,531	3,432,657
Entire TAL	**11,382,372**	**948,531**	**3,477,947**	**1,738,974**	**12,172,815**	**60,864,074**

KAILALI DISTRICT : SAMPLE

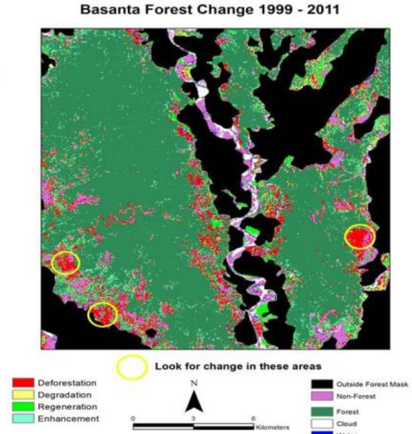
Basanta Forest Condition 1999 (Kailali District)



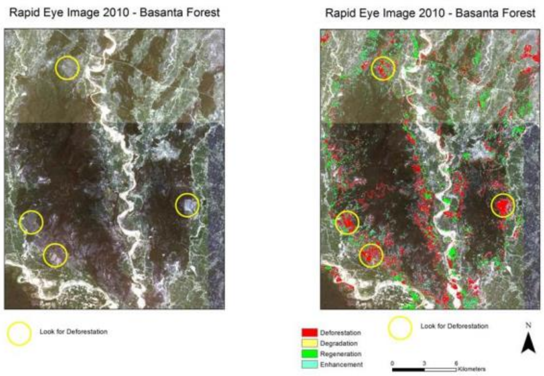
Basanta Forest Condition 2011 (Kailali District)

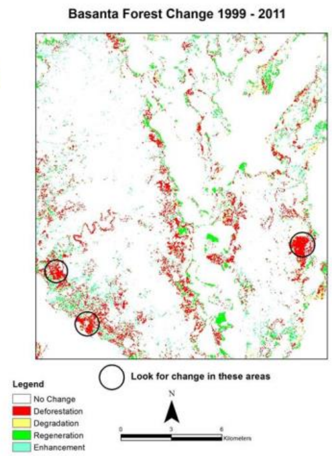


Basanta Forest Change 1999 - 2011

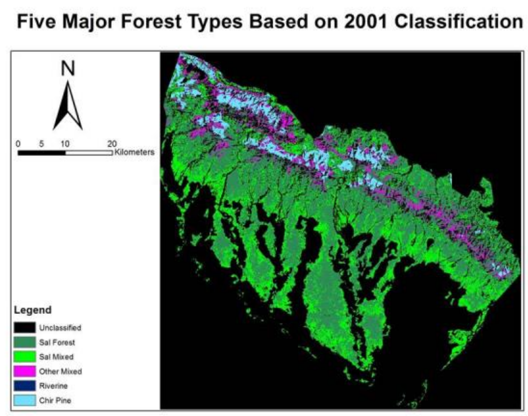


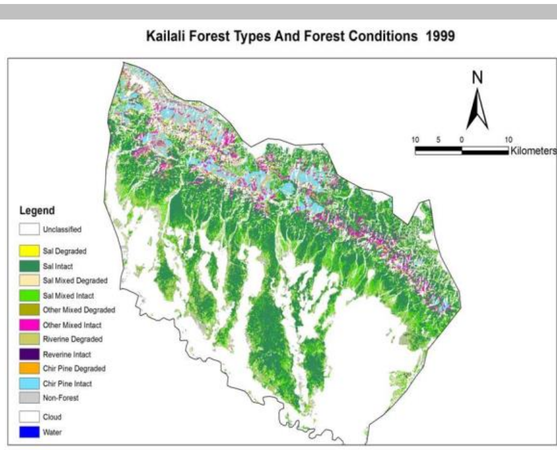
RAPID EYE: FOREST CHANGE DETECTION '99-'11

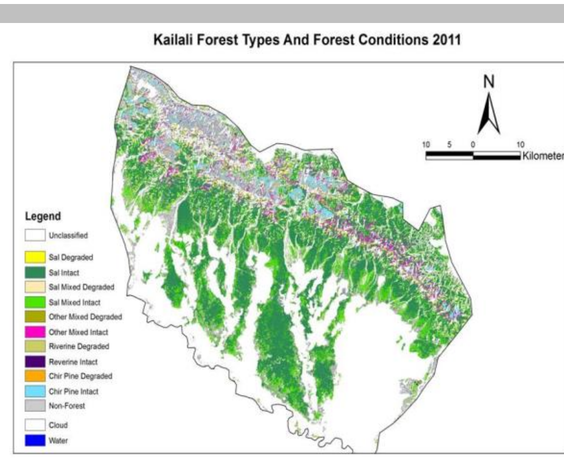




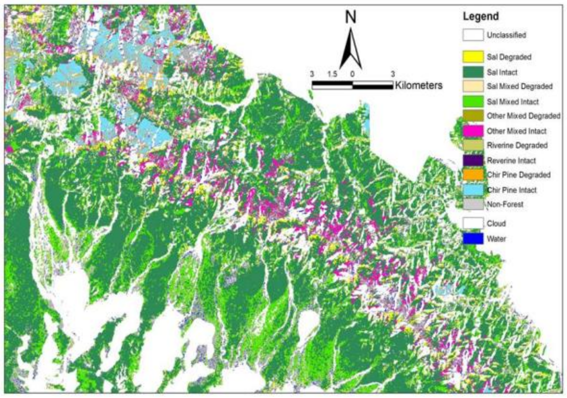
OVERLAYING
4 FOREST TYPES & CONDITIONS



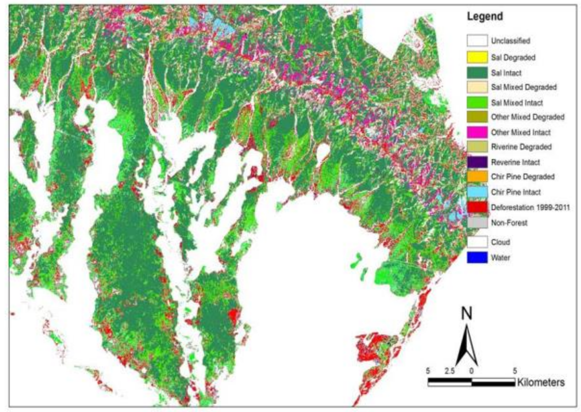




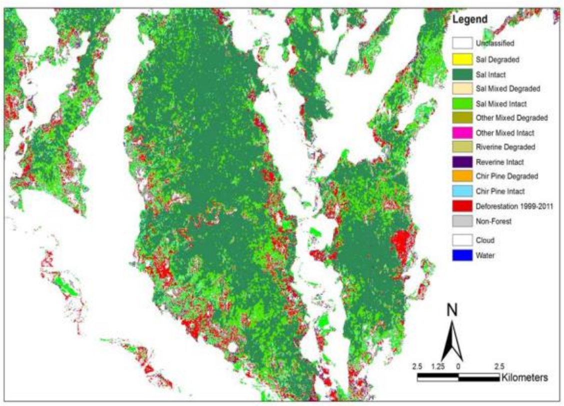
Kailali Forest Types And Forest Conditions 2011



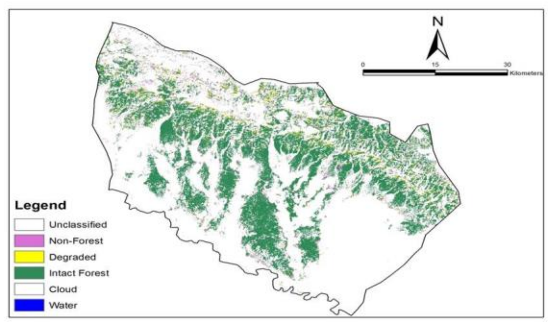
Forest Types And Forest Conditions between 1999 & 2011



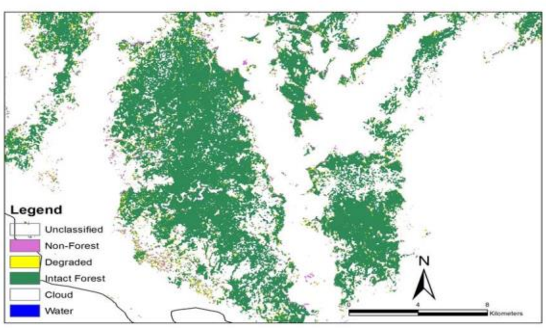
Forest Types And Forest Conditions between 1999 & 2011



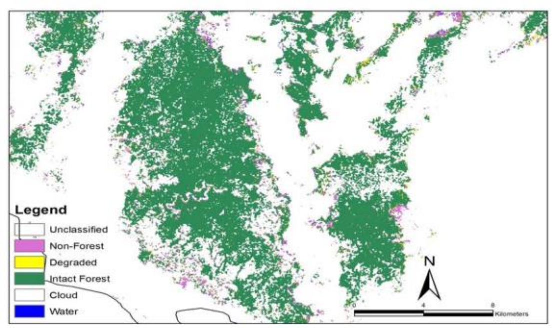
KAILALI FOREST CONDITIONS 2011



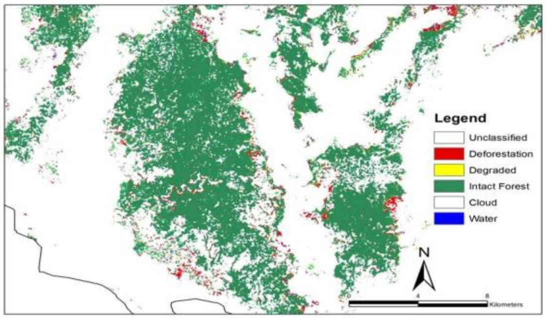
BASANTA SAL FOREST CONDITION - 1999



BASANTA SAL FOREST CONDITION - 2011



BASANTA SAL FOREST CONDITION – 1999-2011

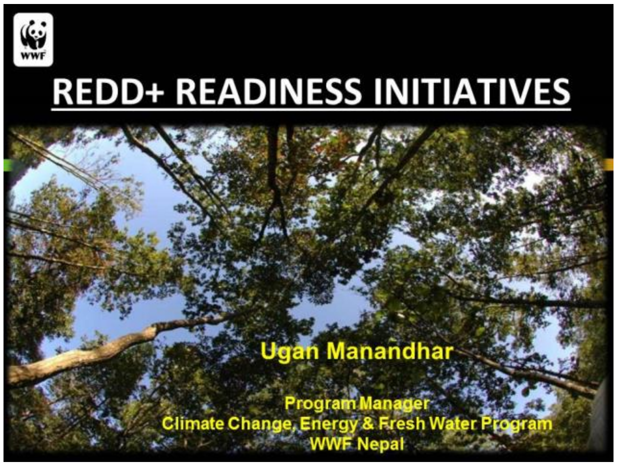


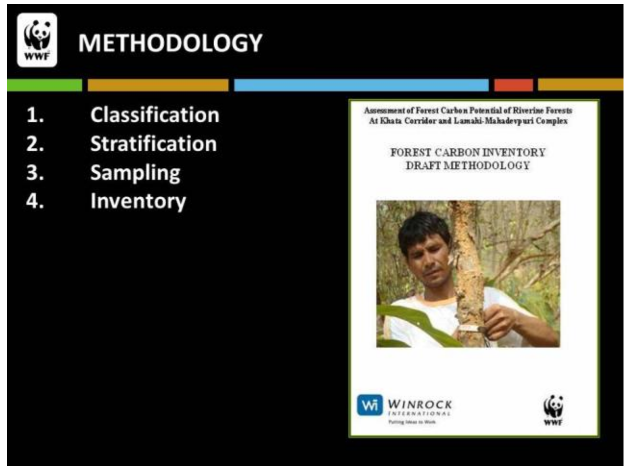
METHODS

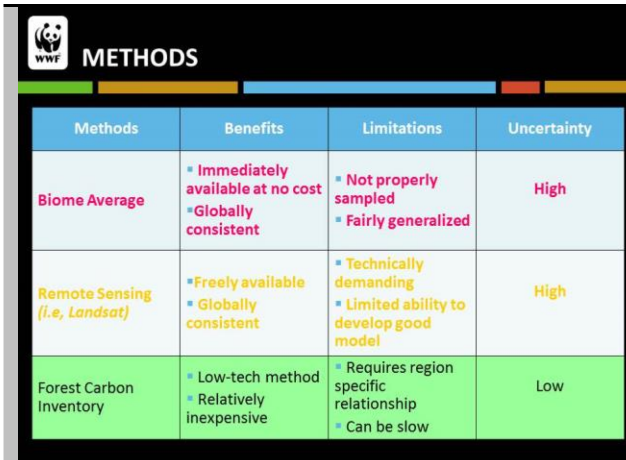
ImgTools (software), Imazon, Brazil :

- Preprocessing Landsat Images
  - Haze correction
  - Radiometric correction
  - Derive top of the atmosphere (TOA) reflectance
- Spectral Mixture Analysis (SMA)
  - GV - Green vegetation
  - GVs – Shade normalized green vegetation
  - NPV - Non-photosynthesis (brown) vegetation
  - NDFI – Normalized Difference Fractional Index
  - Cloud and Water

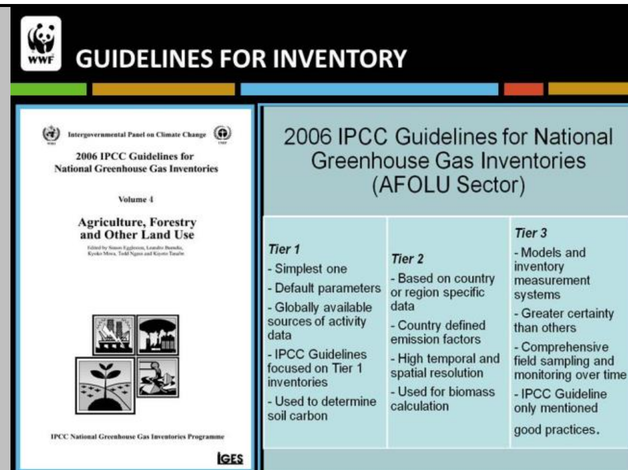
COMMENTS!

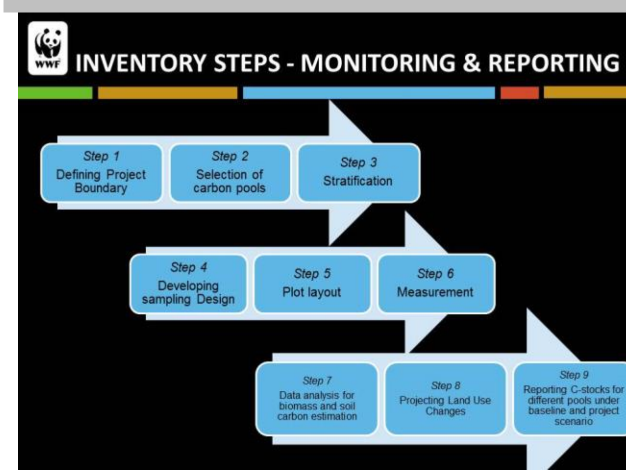


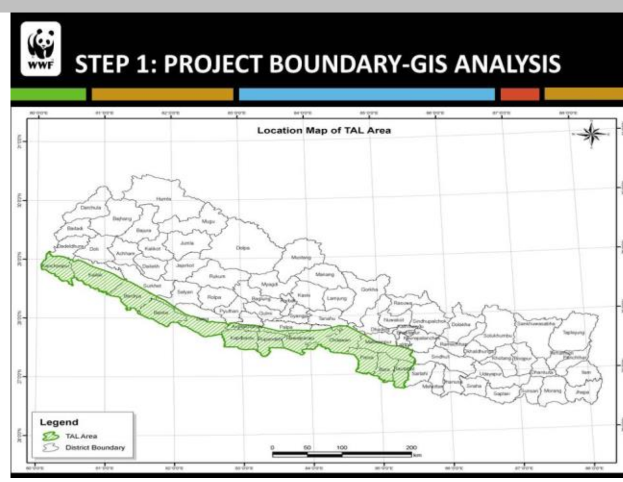




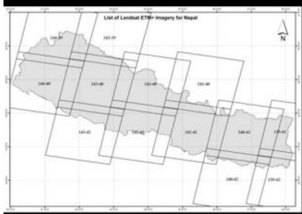
Methods	Benefits	Limitations	Uncertainty
Biome Average	Immediately available at no cost; Globally consistent	Not properly sampled; Fairly generalized	High
Remote Sensing (i.e, Landsat)	Freely available; Globally consistent	Technically demanding; Limited ability to develop good model	High
Forest Carbon Inventory	Low-tech method; Relatively inexpensive	Requires region specific relationship; Can be slow	Low







IMAGE



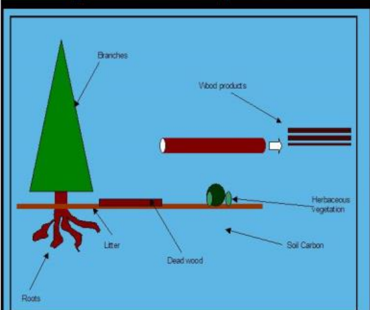
Landsat TM/ETM Scene Path/Row

Year	p141r041	p142r041	P143r041	P144r040
1990	31-Oct 89	07-Nov 89	17-Nov 90	23-Oct 90
1999	04-Nov 99	13-Dec 99	17-Oct 99	09-Nov 99
2000	21-Oct 00	15-Dec 00	20-Nov 00	11-Nov 00
2001	27-Dec 01	03-Nov 01	25-Dec 01	27-Sep 01
2002	28-Nov 02	03-Nov 02	25-Oct 02	01-Nov 02
2009	07-Nov 09	30-Nov 09	20-Oct 09	11-Oct 09

IMAGE ANALYSIS

Rikimaru, 2002

STEP 2: CARBON POOLS



Above Ground Biomass

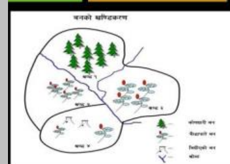
Below Ground Biomass

Shrubs

Litter

Soil Organic Carbon

STEP 3: STRATIFICATION BASED ON ACTIVITY



1. Intact
2. Deforested
3. Degraded
4. Regeneration
5. Enhancement

STEP 4: SAMPLING DESING & VARIANCE ANALYSIS

Variance Analysis:

Step I. Identify the desired precision level

(± 10 percent of the mean at the 95 % confidence interval is frequently used)

Step II. Identify the area or preliminary data

(6-10 plots per stratum will suffice for variance analysis)

Step III. Estimate Carbon stock per tree, per plot, per ha and mean carbon stock/ha

Step IV. Calculate Standard deviation of carbon (Ton C/ha) of all plots

Step V. Calculate the required number of plots using following equations:

STEP 4: SAMPLING DESIGN & VARIANCE ANALYSIS

$$n = \frac{(N \times s)^2}{\frac{N^2 \times E^2}{t^2} + N \times s^2}$$

Source: Pearson et al. (2005)

Where:

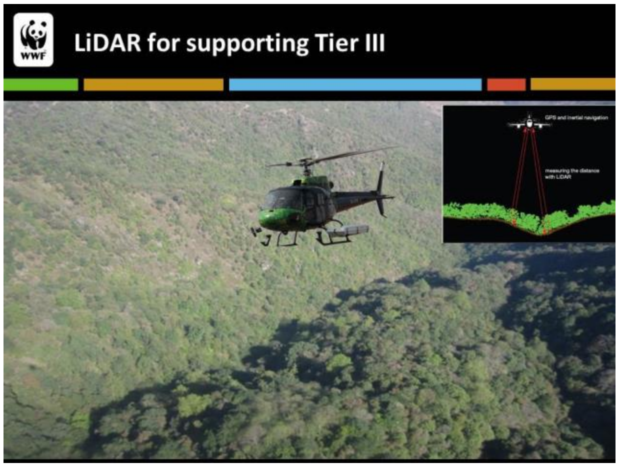
E = Allowable error or the desired half-width of the confidence interval. Calculated by multiplying the mean carbon stock by the desired precision (that is, mean carbon stock x 0.1, for 10 per cent precision).

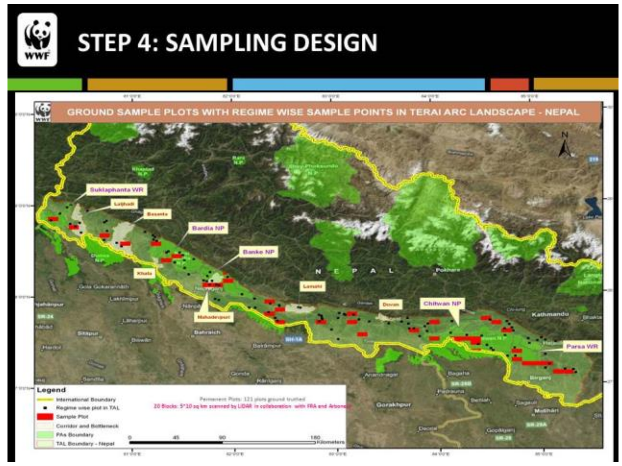
t = The sample statistic from the t-distribution for the 95 per cent confidence level. *t* is usually set at 2 as sample size is unknown at this stage.

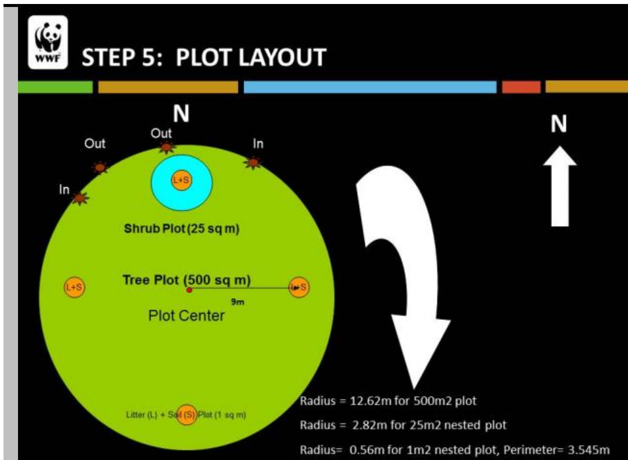
N = Number of sampling units for stratum (= Total area divided by plot area)

n = Number of sampling units in the population

s = Standard deviation of stratum

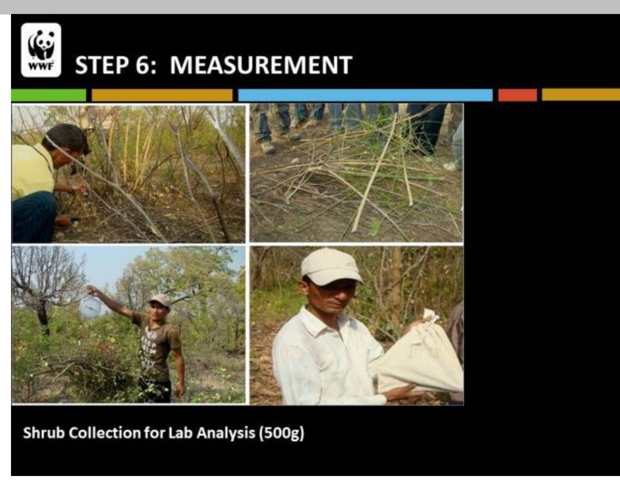

LiDAR for supporting Tier III

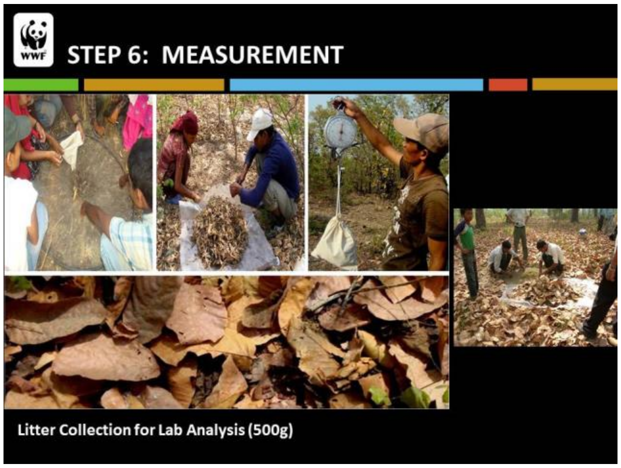

STEP 4: SAMPLING DESIGN
GROUND SAMPLE PLOTS WITH REGIME WISE SAMPLE POINTS IN TERAI ARC LANDSCAPE - NEPAL


STEP 5: PLOT LAYOUT
N
Out
Out
In
In
N
Shrub Plot (25 sq m)
Tree Plot (500 sq m)
9m
Plot Center
Litter (L) + Soil (S) Plot (1 sq m)
Radius = 12.62m for 500m2 plot
Radius = 2.82m for 25m2 nested plot
Radius= 0.56m for 1m2 nested plot, Perimeter= 3.545m

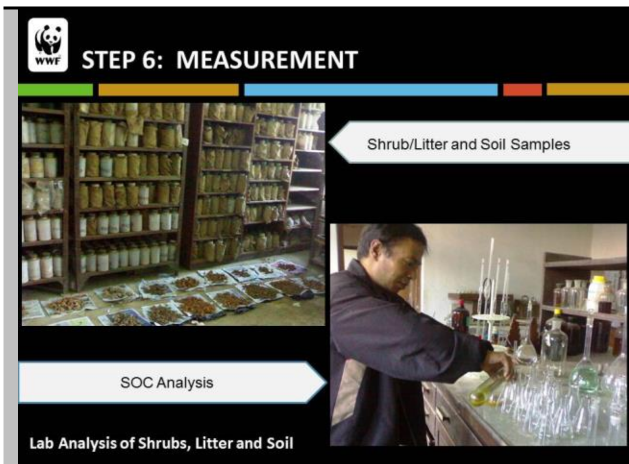

STEP 6: MEASUREMENT
Locating Plot Center with GPS and plot area demarcation

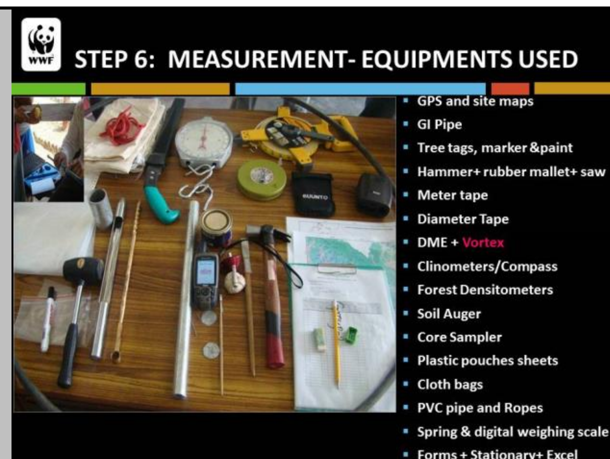

STEP 6: MEASUREMENT
Tree Height, Diameter and Canopy Density


STEP 6: MEASUREMENT
Shrub Collection for Lab Analysis (500g)


STEP 6: MEASUREMENT
Litter Collection for Lab Analysis (500g)


STEP 6: MEASUREMENT
213
213
Soil Collection for Lab Analysis (500g)


STEP 6: MEASUREMENT
Shrub/Litter and Soil Samples
SOC Analysis
Lab Analysis of Shrubs, Litter and Soil


STEP 6: MEASUREMENT- EQUIPMENTS USED
GPS and site maps
GI Pipe
Tree tags, marker &paint
Hammer+ rubber mallet+ saw
Meter tape
Diameter Tape
DME + Vortex
Clinometers/Compass
Forest Densitometers
Soil Auger
Core Sampler
Plastic pouches sheets
Cloth bags
PVC pipe and Ropes
Spring & digital weighing scale
Forms + Stationary+ Excel


STEP 6: FIELD MONITORING- HOT CHECKS


STEP 6: FIELD MONITORING- COLD CHECKS

STEP 7: DATA ANALYSIS

Carbon pools	Method
AGB	• Plot method
Shrubs and Litter	• Plot method • Laboratory Studies
BGB	• Root: Shoot ratio
SOC	• Field sampling • Laboratory studies

STEP 7: DATA ANALYSIS

- Aboveground Biomass (AGB) Calculation

Ecological domain description	Model	Source
Altitude: 550 m asl Rainfall: =1200 mm Dry months: 7 Forest type: Dry tropical	ln (AGB)= -2.235+0.916 ln (D^2Hp)	Chave *et al* (2005)

- Carbon Fraction of Aboveground Biomass (AGB)

Domain	Part of Tree	Carbon Fraction (CF) Mg C (Mg d.m.)$^{-1}$	Source
Tropical	All	0.47 (0.44-0.49)	IPCC (2006)

STEP 7: DATA ANALYSIS

Below ground Biomass (BGB) Calculation

Domain	Ecological Zone	Aboveground Biomass	Ratio (R) Mg root (Mg shoot)$^{-1}$	Reference
Tropical	Tropical dry forest	Aboveground biomass <20 Mg ha^{-1}	0.56 (0.28-0.68)	Mokany *et al.* 2006
		Aboveground biomass >20 Mg ha^{-1}	0.28 (0.27-0.28)	

STEP 7: DATA ANALYSIS

- Soil Organic Carbon (SOC) Calculation

- Bulk Density Calculation
- SOC % determination by **Colorimetric Method** with External Heating

SOC (Mg ha-1) = (Soil Bulk Density (gm/cm3) × Soil depth (cm) × C) × 100

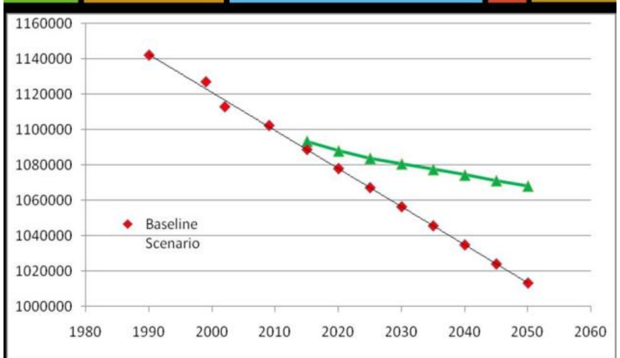
Source: Pearson et al (2005)

STEP 8: PROJECTING DEFORESTATION

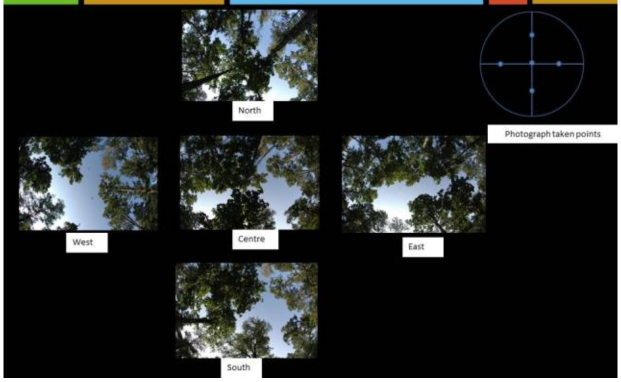
	Baseline Scenario		Project Scenario	
Year	Remaining Forest Area (ha)	Deforestation (ha)	Remaining Forest Area (ha)	Avoided Deforestation (ha)
1990	1,141,992			
1999	1,126,961			
2002	1,112,888			
2009	1,102,300			
2015	1,088,745	13,555	1,093,578	4,833
2020	1,077,981	10,764	1,088,088	10,107
2025	1,067,217	10,764	1,083,930	16,713
2030	1,056,454	10,764	1,080,777	24,323
2035	1,045,690	10,764	1,077,632	31,942
2040	1,034,927	10,764	1,074,497	39,570
2045	1,024,163	10,764	1,071,371	47,208
2050	1,013,400	10,764	1,068,254	54,854

0.19% 0.13%

STEP 8: PROJECTING DEFORESTATION



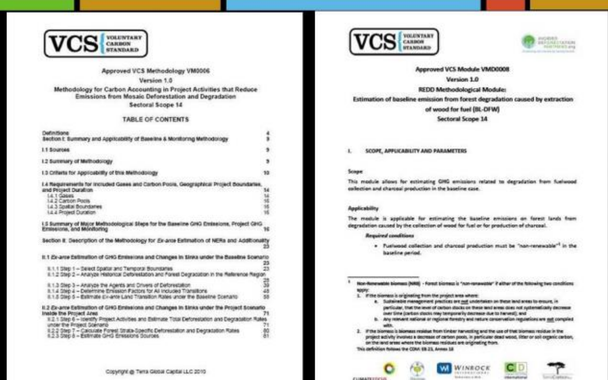
STEP 8: PROJECTING DEGRADATION



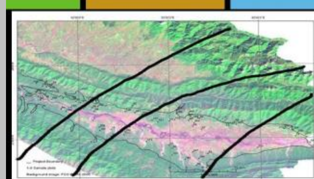
STEP 8: PROJECTING DEGRADATION

Year	Stratum 2	Stratum 3	Stratum 4
1990	161,814	848,769	131,409
2009	222,510	762,592	117,197
Change in Area (ha)	**60,696**	**(86,177)**	**(14,212)**

STEP 8: DEGRADATION



PROBLEMS



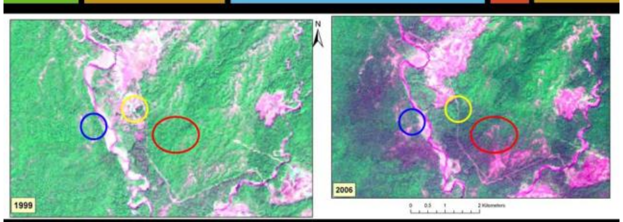
Land-sat images- Image gaps

IRS images Bandwidth not sufficient

Accessibility to points

Points Shift

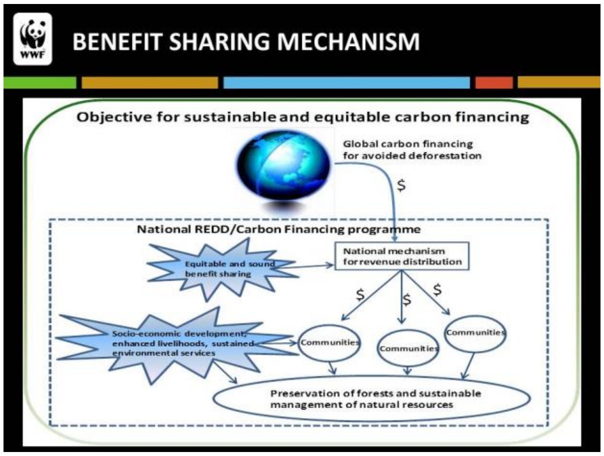
LEAKAGE



Example of Land cover change between 1999-2006 at Samsergunj area, Banke

ISSUES

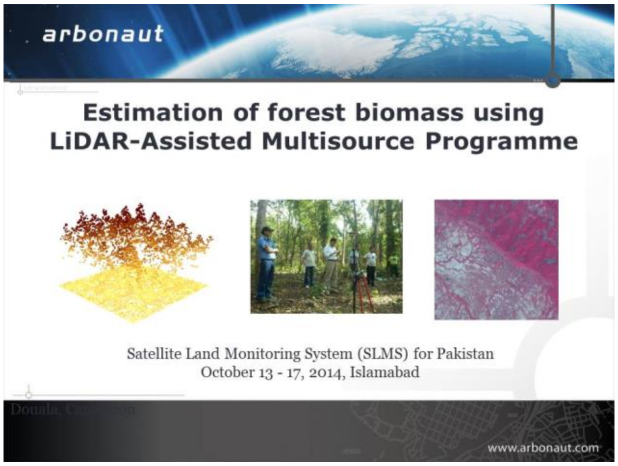
- Natural resource sharing
- Governance of funds
- Image quality and time series image data
- Data Management (central and local level) and Institutions
- Software and computational tools its use at local & central level
- Stratification modalities and Accessibility to sites
- Biometric/ Allometric Equations (destructive destruction not done)
- Availability of Post and Ex- Ante data
- Leakage control
- Setting up the reference levels- challenging: FREL/FRL

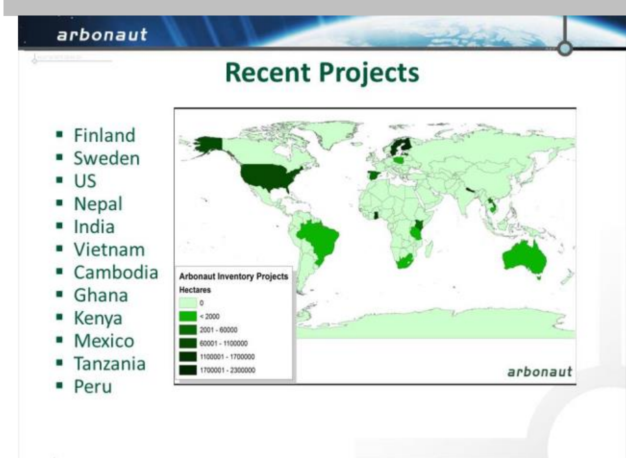

BENEFIT SHARING MECHANISM
Objective for sustainable and equitable carbon financing
Global carbon financing
for avoided deforestation
$
National REDD/Carbon Financing programme
National mechanism
for revenue distribution
Equitable and sound
benefit sharing
$
$
$
Socio-economic development,
enhanced livelihoods, sustained
environmental services
Communities
Communities
Communities
Preservation of forests and sustainable
management of natural resources

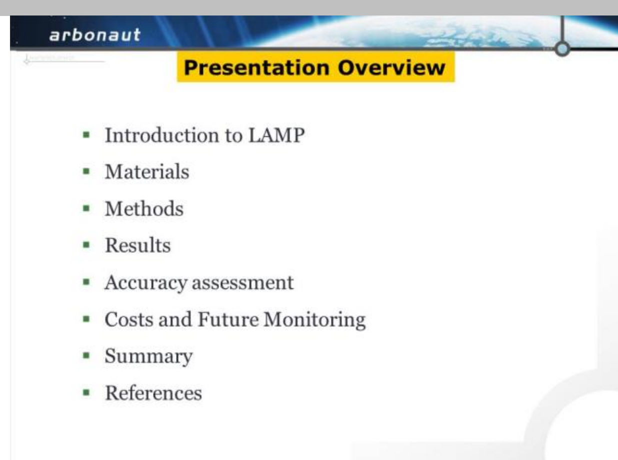

THANK YOU

Annex III(c)

Presentations delivered by Mr. Basanta Gautam



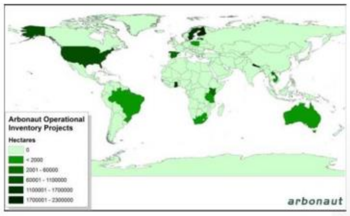




Leassons learned

Case studies in tropics

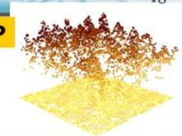
- Ghana (some hills, very dense vegetation, just mean AGB for forest types)
- Nepal (large-area LAMP project for REDD+ reference level)
- Lao PDR (pilot project in a flat terrain, small area)



+ experiences from LiDAR based inventories in semi-natural boreal forest and plantations

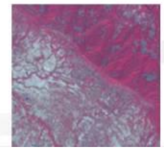
- Finland, Sweden, Spain, Ireland, Poland, Latvia, Brazil

Introduction - LAMP

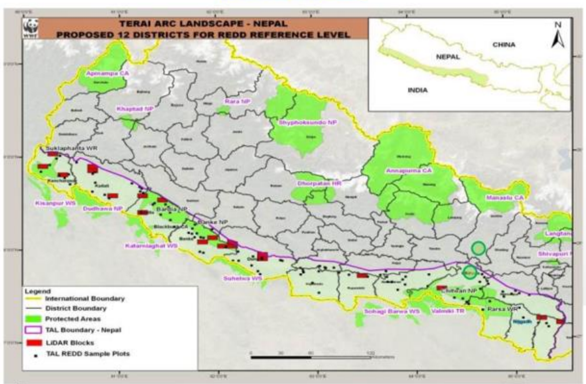


- Samples (1-10%) of LiDAR data to calibrate **satellite models**;

- Reference field sample plots to calibrate/validate **LiDAR models**;
- Medium (e.g.Landsat) to high resolution (e.g.Rapideye) satellite imagery for **wall-to-wall biomass** map.

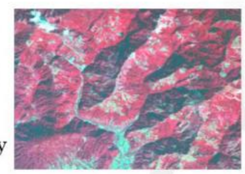


Study area



Materials: Satellite Data

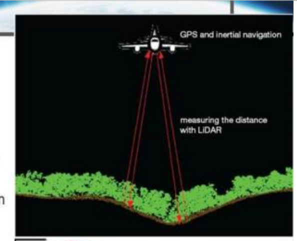
- Satellites can collect large amounts of image data over a wide geographical area with a high temporal frequency.
- Wall-to-wall carbon density map.
- Provides information on species composition.
- Provides 2D (x,y) geometry, whereas LiDAR provides 3D (x, y, z) geometry.
- Using old satellite data provides a way to define historical forest carbon baselines.

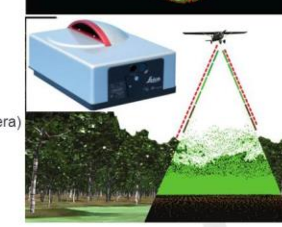


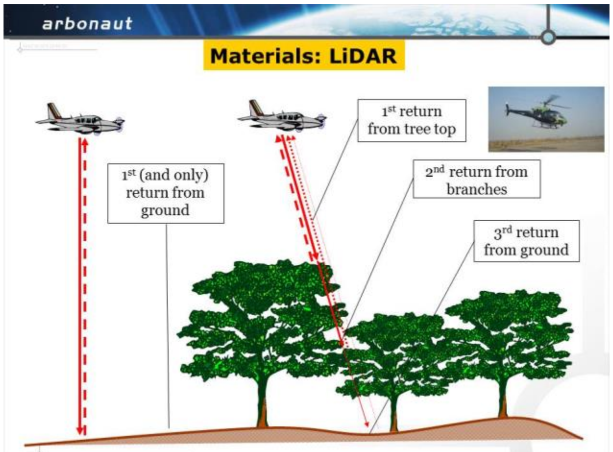
Materials: LiDAR

What is LiDAR?

- LiDAR (Light Detection And Ranging) is an active sensor which uses laser scanner
- LiDAR sends laser beam to the forests and receive multiple return signals from the forests
- LiDAR provides precise 3D (*X, Y, Z*) information (*horizontal and vertical*) of the vegetation
- LiDAR can be operated during day and night
- Georeferencing is not needed
- High resolution CIR orthophotos (digital camera)
- No effect of sun illumination, shading and weather conditions



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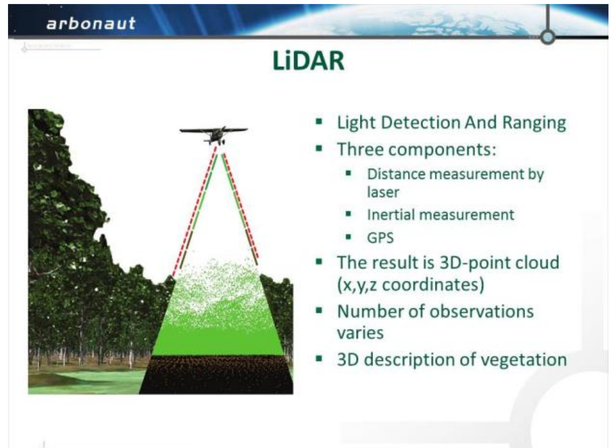
Materials: LiDAR
1st return
from tree top
1st (and only)
return from
ground
2nd return from
branches
3rd return
from ground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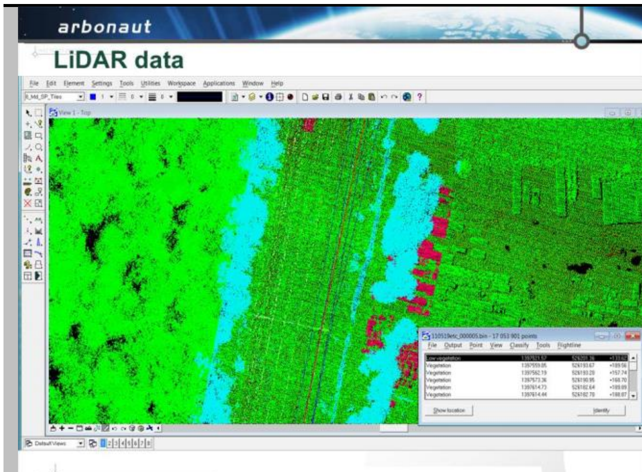
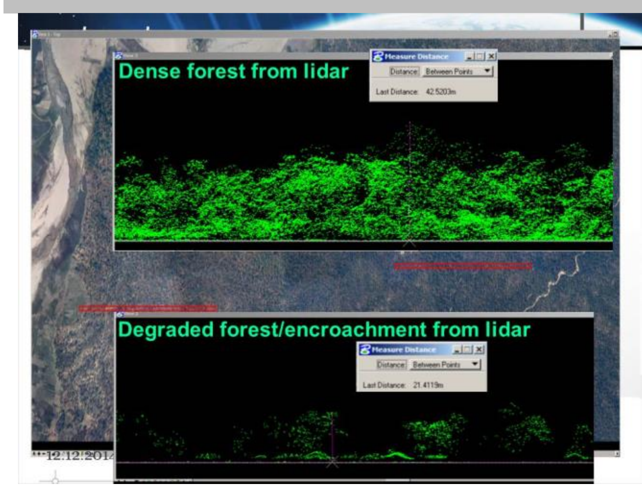
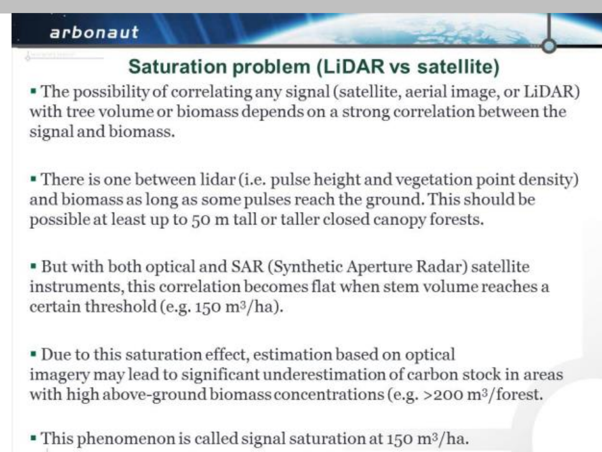
LiDAR
Light Detection And Ranging
Three components:
Distance measurement by laser
Inertial measurement
GPS
The result is 3D-point cloud (x,y,z coordinates)
Number of observations varies
3D description of vegetation


arbonaut
LiDAR data


arbonaut
LiDAR data


Dense forest from lidar
Measure Distance
Last Distance: 42.5203m
Degraded forest/encroachment from lidar
Measure Distance
Last Distance: 21.4119m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Saturation problem (LiDAR vs satellite)
The possibility of correlating any signal (satellite, aerial image, or LiDAR) with tree volume or biomass depends on a strong correlation between the signal and biomass.
There is one between lidar (i.e. pulse height and vegetation point density) and biomass as long as some pulses reach the ground. This should be possible at least up to 50 m tall or taller closed canopy forests.
But with both optical and SAR (Synthetic Aperture Radar) satellite instruments, this correlation becomes flat when stem volume reaches a certain threshold (e.g. 150 m3/ha).
Due to this saturation effect, estimation based on optical imagery may lead to significant underestimation of carbon stock in areas with high above-ground biomass concentrations (e.g. >200 m3/forest.
This phenomenon is called signal saturation at 150 m3/ha.

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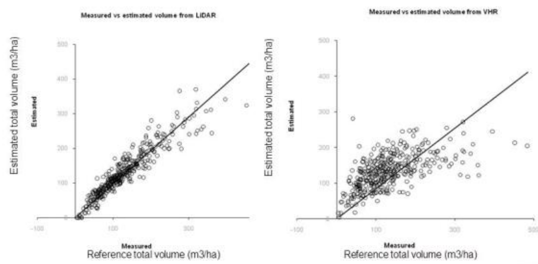
Saturation, optical satellite imagery



Peuhkurinen et al. (2010)

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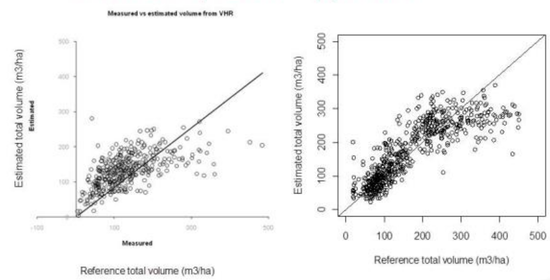
Saturation, LAMP approach



Gautam *et al.* (2010)

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Lidar transects can be random or systematic

- Lidar can be captured by systematic strips or by random blocks
- Block selection can be weighted
- A typical weight function should be based on a land use or forest type map
- Forest types with high internal variability should be given a higher weight
- The bias introduced by weighting is removed in the estimation stage by inverse weighting of the corresponding estimates in regression

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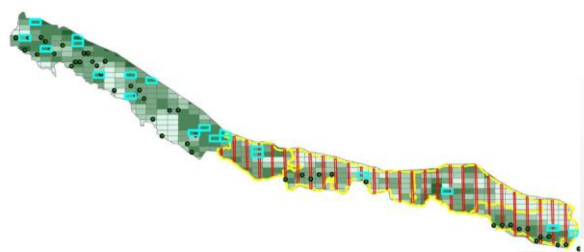
Comparison of blocks and systematic strips, and selected blocks



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Specifications for the LiDAR scanning

Average flying altitude above ground level	2200 m
Flying speed	80 knots (148 km)/hour
Sensor pulse rate	52.9 khz
Sensor scan speed	20.4 lines per second
Nominal outgoing pulse density at ground level	0.8 points per square meter
Scanning field of view (FOW) half angle	20 degrees
Swath width at ground level	1601.47 meters
Point spacing on the ground (across-track / along-track)	max. 1.88m / max 2.02m

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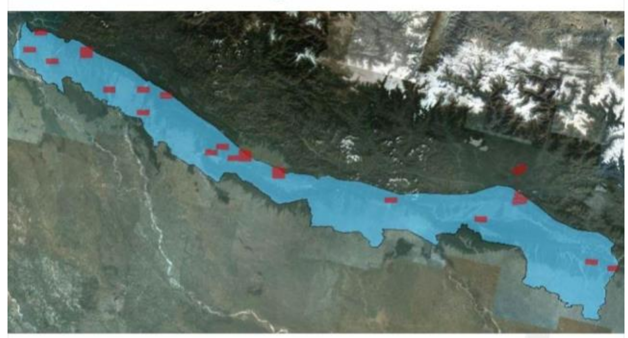
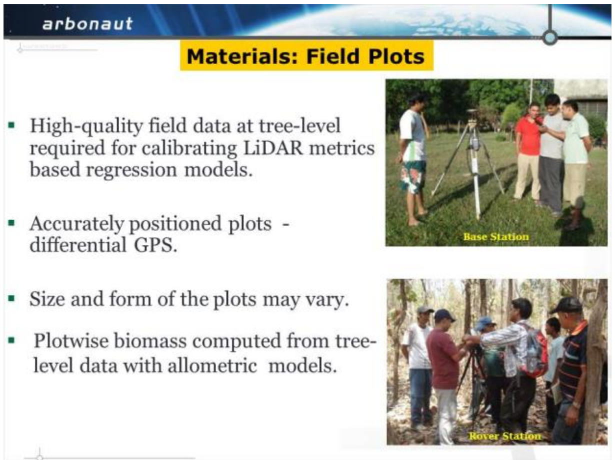
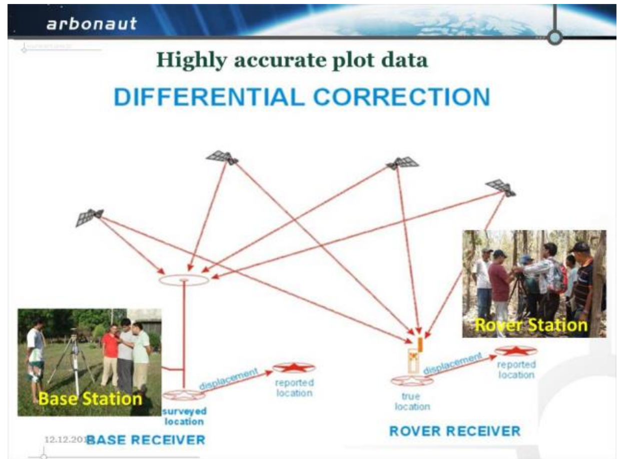
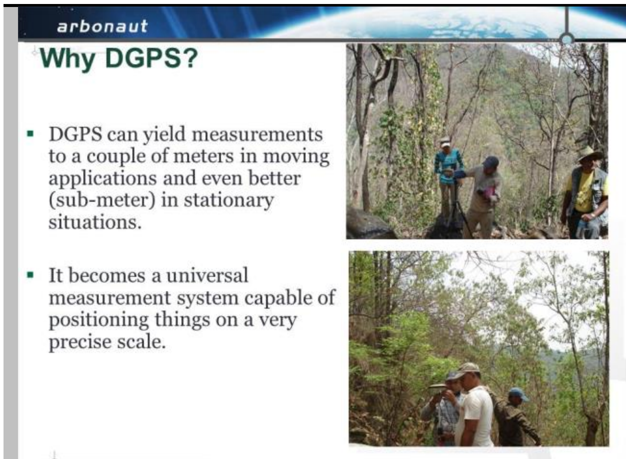
LiDAR blocks and flight lines

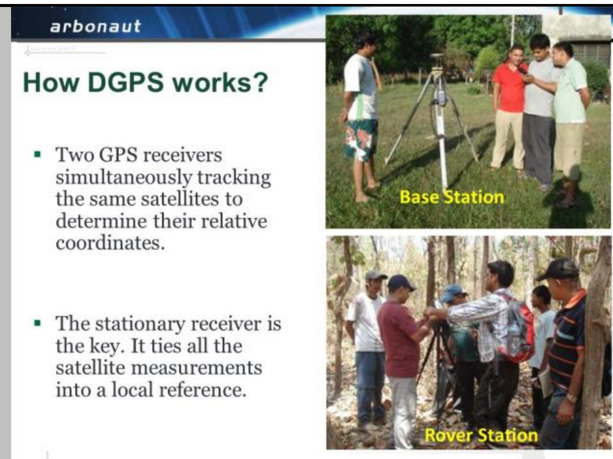


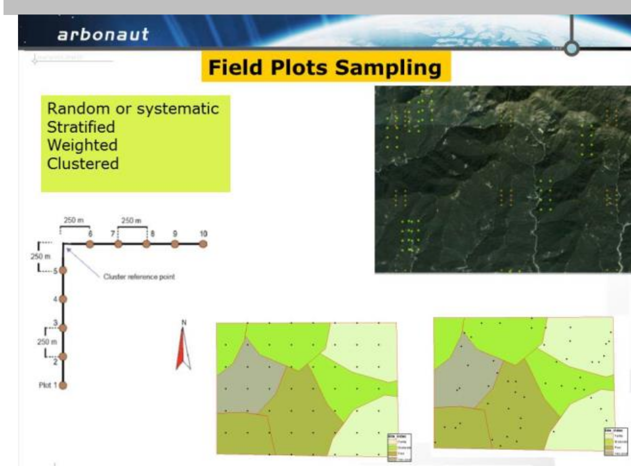
UN-REDD PROGRAMME

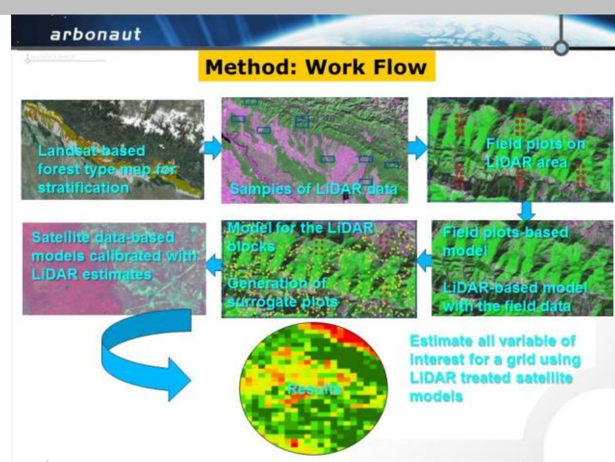


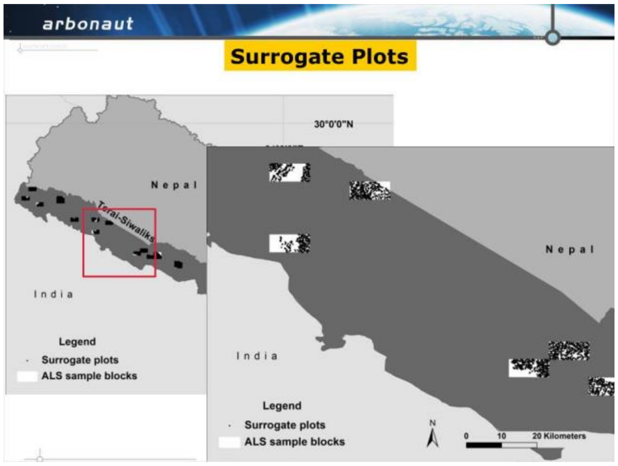








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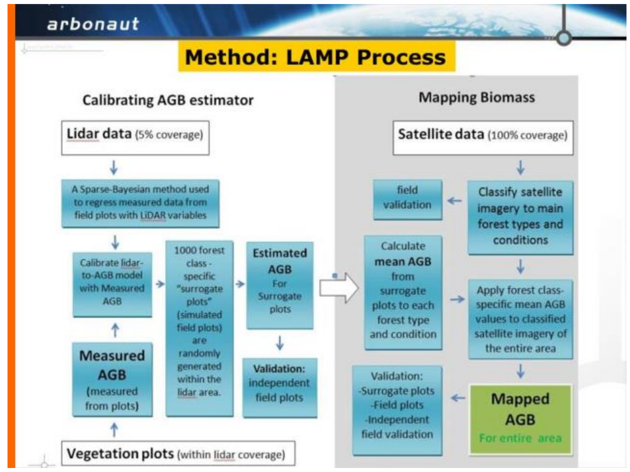
Surrogate Plots
30°0'0"N
Nepal
Terai-Siwaliks
India
Legend
Surrogate plots
ALS sample blocks
Nepal
India
Legend
Surrogate plots
ALS sample blocks
N
0 10 20 Kilometers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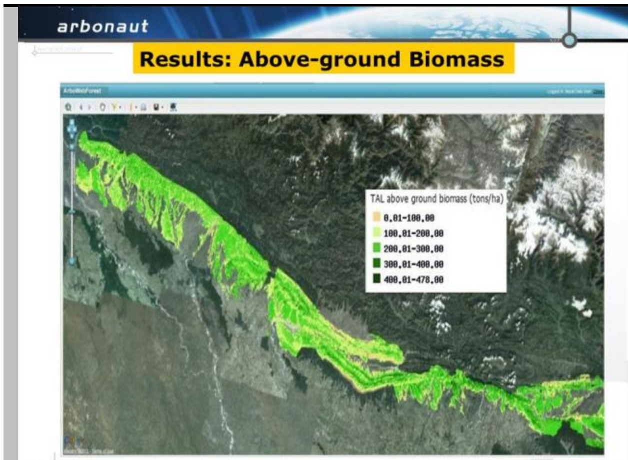
Method: LAMP Process
Calibrating AGB estimator
Lidar data (5% coverage)
A Sparse-Bayesian method used to regress measured data from field plots with LiDAR variables
Calibrate lidar-to-AGB model with Measured AGB
Measured AGB (measured from plots)
1000 forest class - specific "surrogate plots" (simulated field plots) are randomly generated within the lidar area.
Estimated AGB For Surrogate plots
Validation: independent field plots
Vegetation plots (within lidar coverage)
Mapping Biomass
Satellite data (100% coverage)
field validation
Classify satellite imagery to main forest types and conditions
Calculate mean AGB from surrogate plots to each forest type and condition
Apply forest class-specific mean AGB values to classified satellite imagery of the entire area
Validation: -Surrogate plots -Field plots -Independent field validation
Mapped AGB
For entire area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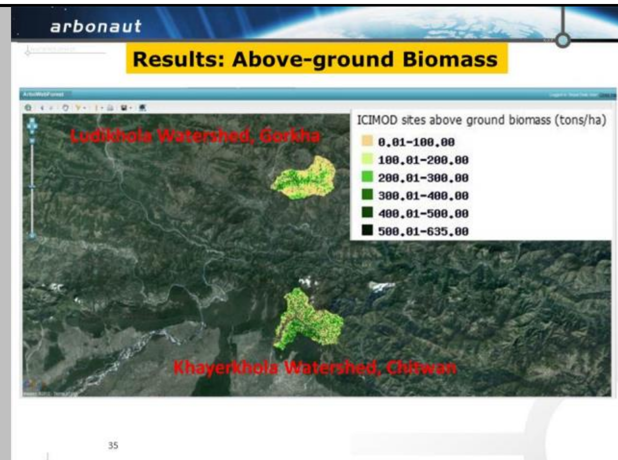
Results: Above-ground Biomass
TAL above ground biomass (tons/ha)
0.01-100.00
100.01-200.00
200.01-300.00
300.01-400.00
400.01-478.00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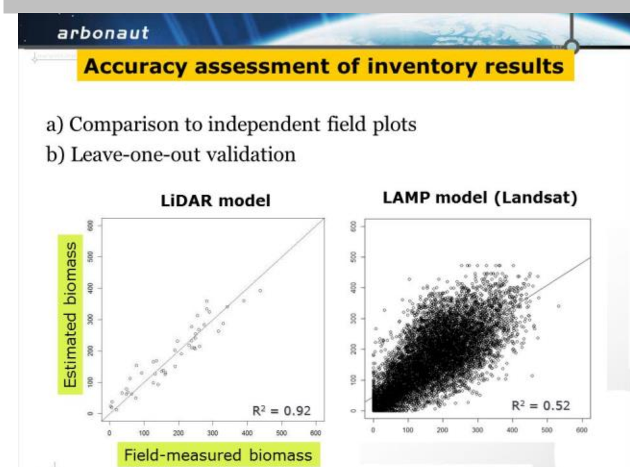
Results: Above-ground Biomass
ICIMOD sites above ground biomass (tons/ha)
0.01-100.00
100.01-200.00
200.01-300.00
300.01-400.00
400.01-500.00
500.01-635.00
Ludikhola Watershed, Gorkha
Khayerkhola Watershed, Chitwan
35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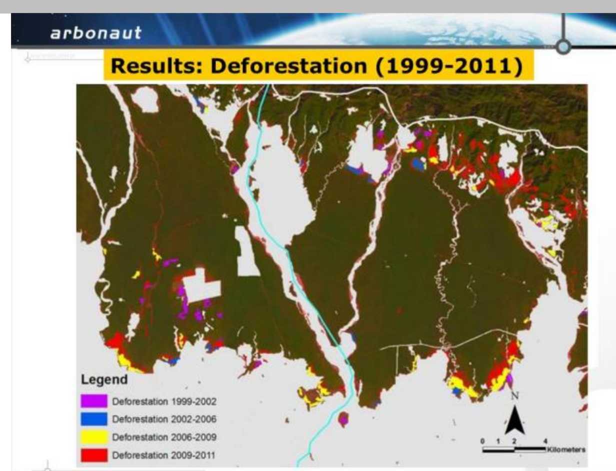
Accuracy assessment of inventory results
a) Comparison to independent field plots
b) Leave-one-out validation
LiDAR model
LAMP model (Landsat)
Estimated biomass
Field-measured biomass
R² = 0.92
R² = 0.52
0
100
200
300
400
500
600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Results: Deforestation (1999-2011)
Legend
Deforestation 1999-2002
Deforestation 2002-2006
Deforestation 2006-2009
Deforestation 2009-2011
N
0 1 2 4 Kilometers

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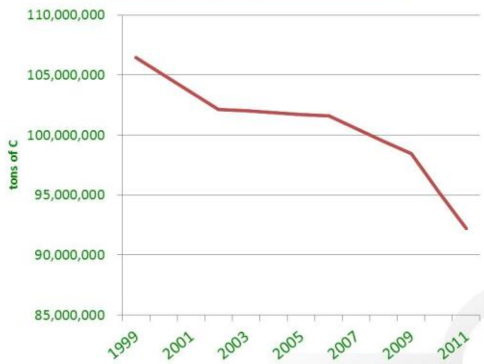
Historical Carbon Stock Loss



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Reference Level (result) field verification

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Costs and Future Monitoring

- The initial cost of LiDAR acquisition is of the same order as the cost of a field campaign, when 1-5 % coverage is used in LAMP
- But LiDAR and comprehensive field campaigns are needed only once
- Subsequent monitoring is based on new satellite images to which the LAMP models are applied
- Only validation plots are necessary, but plots can be collected for assessing other carbon pools

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Summary: LAMP benefits

- LiDAR can produce large cost savings if field plots are partly replaced with LiDAR surrogate field plots;
- LAMP can be used to estimate other forest variables, basal area, stem volume, tree height, simultaneously with AGB;
- LAMP result are updatable if, for example, better allometric models are available or better RS data are available;
- LAMP helps to overcome the saturation of biomass estimates when producing wall-to-wall biomass density maps using satellite data.

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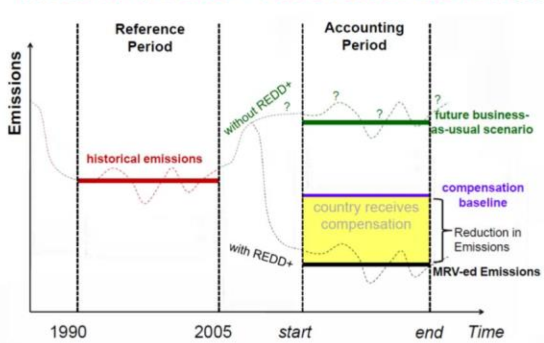
What is a REDD+ Reference Level?...



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http://www.dfrs.gov.np/downloadfile/Banko%20Janakari%20Vol%2024-1_1413107624.pdf

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http://report.arbonaut.com/arbo_site_uploaded_files/pdf/pdf/Estimation%20of%20Forest%20Carbon%20Using%20LiDAR-Assisted%20Multi-source%20Programme%20%28LAMP%29%20in%20Nepal.pdf

Integration of airborne LiDAR, satellite imagery, and field measurements using two-phase sampling method for forest biomass estimation in tropical forests. (Lao PDR).
http://report.arbonaut.com/arbo_site_uploaded_files/pdf/pdf/Integration%20of%20airborne%20LiDAR,%20satellite%20imagery,%20and%20field%20measurements%20using%20a%20two-phase%20sampling%20method%20for%20forest%20biomass%20estimation%20in%20tropical%20forests.pdf

Estimation of above ground Forest biomass and Carbon stock by Integrating LiDAR, satellite image and field measurement in Nepal.
http://www.isca.in/AGRI_FORESTRY/Archive/v2/i8/1.ISCA-RJAFS-2014-031.pdf