National Aeronautics and Space Administration

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Remote sensing of forest cover and change assessment for carbon monitoring

Instructors: Cindy Schmidt, Martin Herold (Wageningen University)

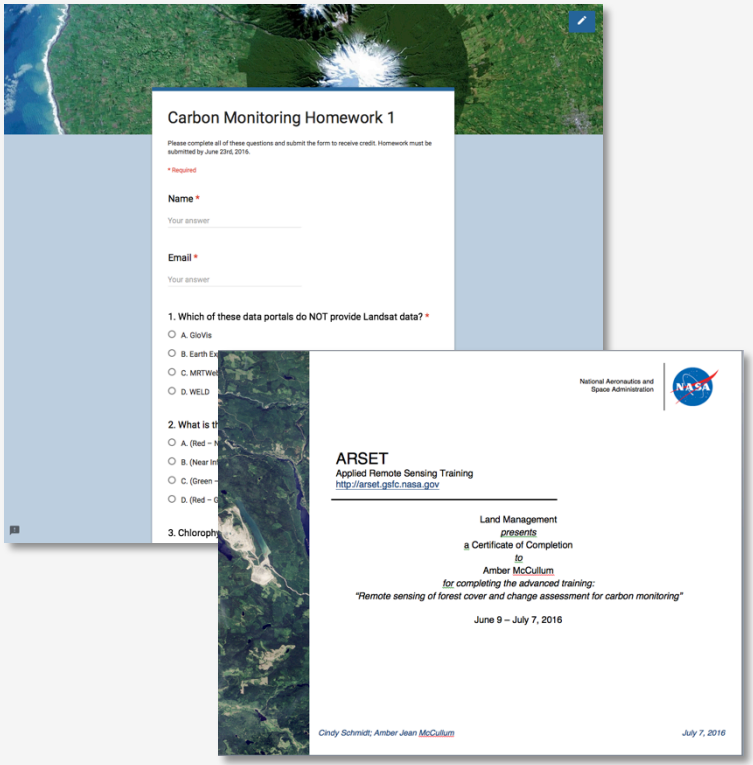
Week 1: June 9, 2016

Course Structure

- One lecture per week – every Thursday from June 9 to July 7 at 1:00-2:30 p.m. and 10:00-11:30 p.m. EDT(-04:00 UTC)
- Please only sign up for and attend the same session each week
  - Lectures
  - Q&A
  - Homework exercises
- Webinar recordings, PowerPoint presentations, in-class exercises, and homework assignments can be found after each session at:
  - http://arset.gsfc.nasa.gov/ecoforecasting/webinars/carbon-monitoring-2016
  - Q&A: Following each lecture and/or by email (cynthia.l.schmidt@nasa.gov) or (amberjean.mccullum@nasa.gov)

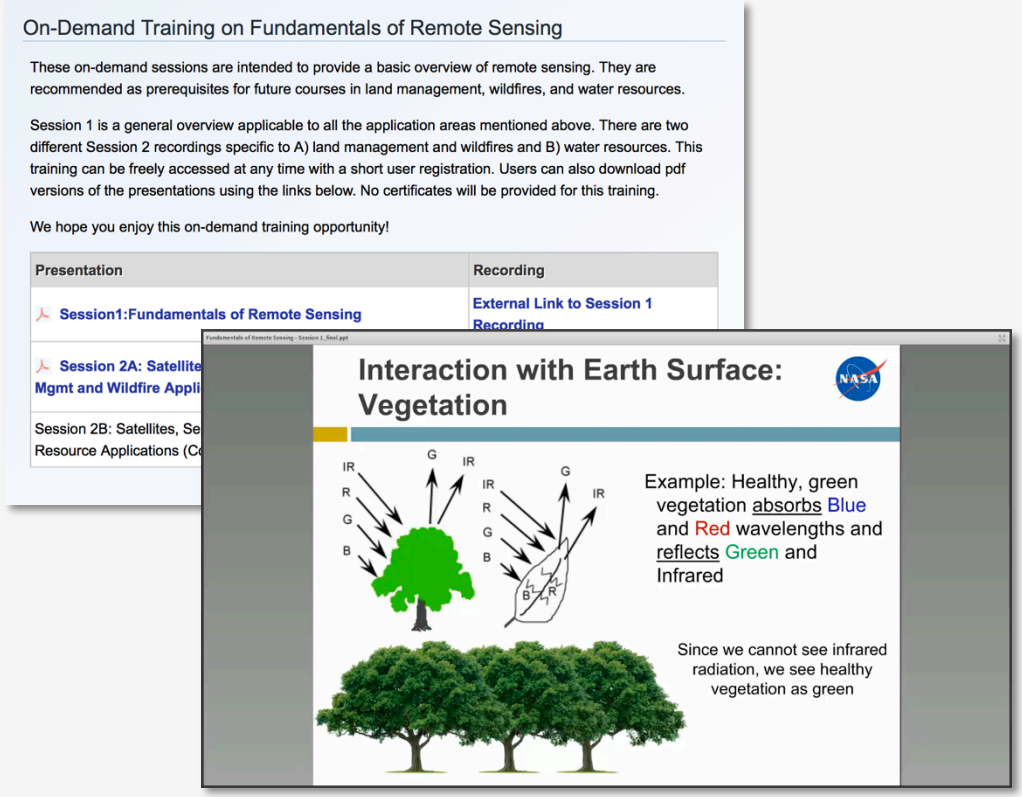
Homework and Certificates

- Homework
  - Answers must be submitted via Google Form
- Certificate of Completion:
  - Attend four out of five live webinars
  - Complete both homework assignments by the deadline (access from ARSET website above)
    - Week 2 HW Deadline: June 30th
  - You will receive certificates approximately 3 months after the completion of the course from: marines.martins@ssaihq.com



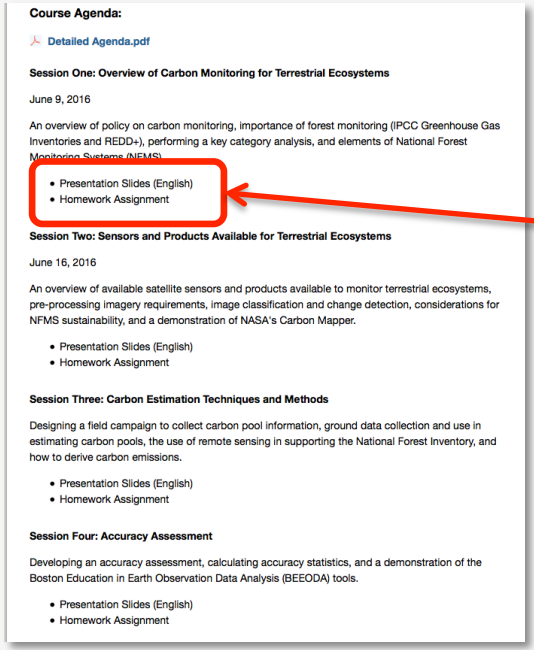
Prerequisite

- Fundamentals of Remote Sensing
  - Sessions 1 and 2A (Land)
  - On-demand webinar available anytime
  - http://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing



Accessing Course Materials

https://arset.gsfc.nasa.gov/land/webinars/carbon-monitoring-2016



Course materials are provided here using each specified link and will be active after each week

Course Objectives

- Provide a basic understanding of carbon monitoring and its global importance
- Show participants how to acquire remotely-sensed imagery and products for carbon monitoring
- Provide techniques for estimating carbon
- Show participants how to develop accuracy assessments
- Provide information about reporting and verifying carbon estimates

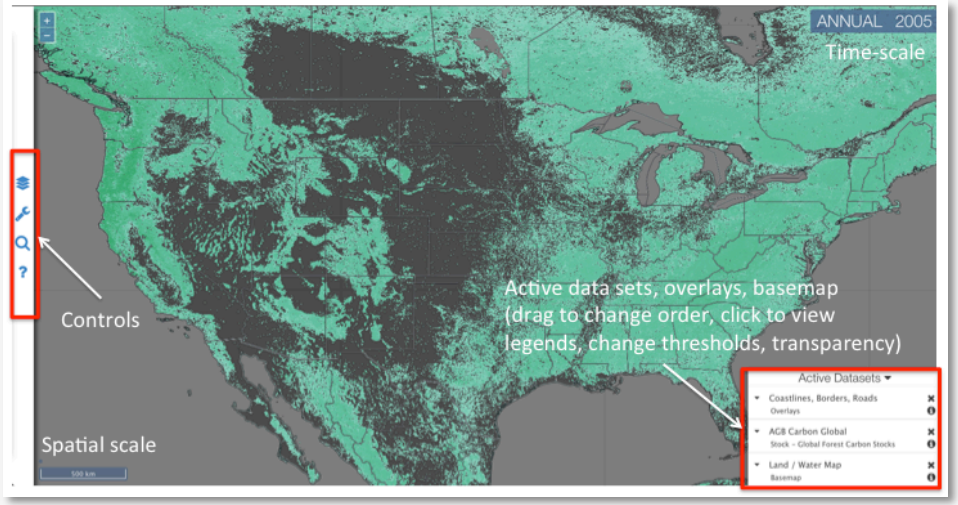
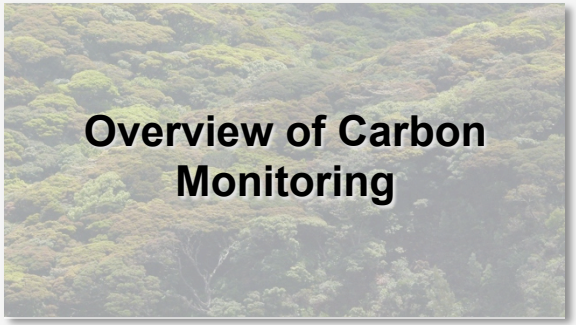


Image Credit: NASA's Carbon Mapper

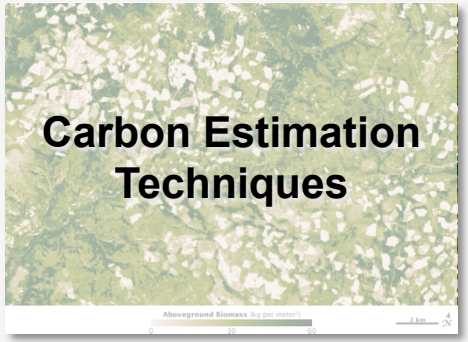
Course Outline

Week 1

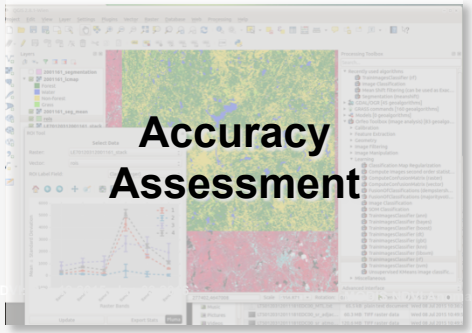


Week 2

Week 3



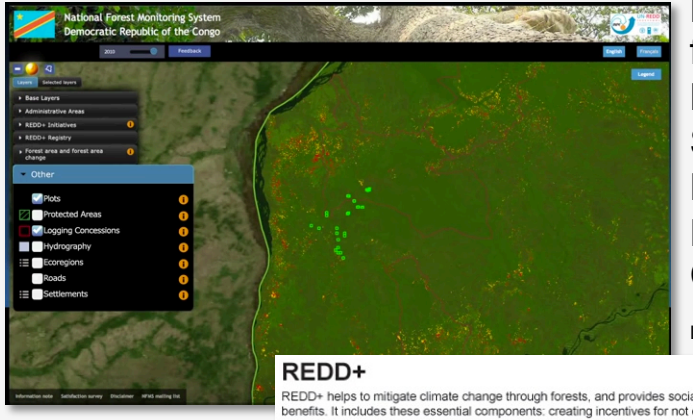
Week 4



Week 5

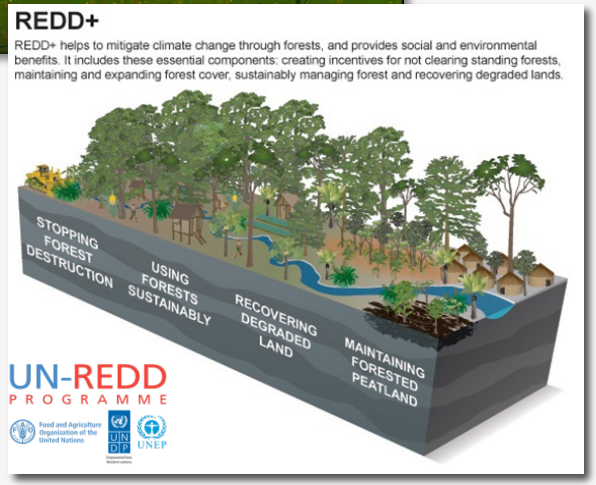
Week 1 Agenda

- Intro to the United Nations Framework Convention for Climate Change (UNFCCC) and the Reducing Emissions from Deforestation and Forest Degradation (REDD)
- Guidelines for Greenhouse gas inventories and carbon and reporting for forest land
- Elements of National Forest Monitoring Systems (NFMS)
- Q&A



National forest Monitoring System Democratic Republic of Congo.

Image credit: UN REDD



Benefits of REDD+ Monitoring

Image credit: UN REDD

Week 1 Materials

- The training materials in this presentation were developed by the Global Observation of Forest Cover and Land Dynamics (GOFC-GOLD), Wageningen University, and World Bank FCPF.

- At the GOFC-GOLD website there are also:
  - Country examples
  - Training exercises
  - Support documents and references

- This presentation (week 1) can also be downloaded from the ARSET website: http://arset.gsfc.nasa.gov/land/webinars/carbon-monitoring-2016

Week 1 Materials

- Websites for accessing the full set of GOFC-GOLD materials:
  - GOFC-GOLD website
    - http://www.gofcgold.wur.nl/redd/Training_modules.php
  - Worldbank FCFP
    - https://www.forestcarbonpartnership.org/redd-training-material-forest-monitoring

Guest Speaker: Martin Herold

Module 1.1 UNFCCC context and requirements and introduction to IPCC guidelines

Module developers:

Martin Herold, Wageningen University

Erika Romijn, Wageningen University

Brice Mora, Wageningen University

After the course the participants should be able to:

- Understand the UNFCCC context and requirements for monitoring and reporting of REDD+ activities
- Explain fundamental concepts of the IPCC guidelines for national greenhouse gas (GHG) inventories and for reporting on forest-related activities

V1, May 2015

WAGENINGEN UR For quality of life

GOFC-GOLD Global Observation of Forest and Land Cover Dynamics

FOREST CARBON PARTNERSHIP FACILITY

Background material

- GOFC-GOLD. 2014. *Sourcebook*. Section 1.

- IPCC good practice guidelines and guidance (various). http://www.ipcc-nggip.iges.or.jp/public/index.html

- GFOI. 2014. Integrating Remote-sensing and Ground-based Observations for Estimation of Emissions and Removals of Greenhouse Gases in Forests: Methods and Guidance from the Global Forest Observation Initiative (MGD).

- Hewson, Steininger, and Pesmajoglou, eds. 2013. REDD+ Measurement, Reporting and Verification (MRV) Manual. USAID-supported Forest Carbon, Markets and Communities Program.

Background material

- UNFCCC. 2013. CP.19 Decisions:
  - Decision 11. Modalities for national forest-monitoring systems. http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=31
  - Decision 12. The timing and the frequency of presentations of the summary of information on how all the safeguards referred to in decision 1/CP.16, appendix I, are being addressed and respected. http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=33
  - Decision 13. Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels. http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=34
  - Decision 14. Modalities for measuring, reporting and verifying. http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=39
  - Decision 15. Addressing the drivers of deforestation and forest degradation. http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=43

Background material

- UNFCCC. 2011. Decision 12/CP.17. Guidance on systems for providing information on how safeguards are addressed and respected and modalities relating to forest reference emission levels and forest reference levels as referred to in decision 1/CP.16
  http://unfccc.int/resource/docs/2011/cop17/eng/09a02.pdf#page=16
- UNFCCC. 2011. Decision 2/CP.17. Outcome of the work of the ad hoc working group on long-term cooperative action under the convention.
  http://unfccc.int/resource/docs/2011/cop17/eng/09a01.pdf#page=4
- UNFCCC. 2010. Decision 1/CP.16. The Cancun Agreements
  http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2
- UNFCCC. 2009. Decision 4/CP.15. Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.
  http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=11
- UNFCCC. 2007. Decision 2/CP.13. Reducing emissions from deforestation in developing countries: approaches to stimulate action.
  http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf#page=8

Outline of lecture

1. Introduction to UNFCCC REDD+ process
2. UNFCCC context and requirements for measurement and reporting of REDD+ activities
3. IPCC guidelines for national GHG inventories and reporting for forest land
    a. Reporting principles
    b. Estimation of carbon emissions

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Tropical forests and climate change

- Tropical forests store significant amounts of carbon in above- and belowground biomass, dead wood, litter, and soil.
- Deforestation impacts global GHG emissions by releasing carbon dioxide (CO_2) to the atmosphere.
- A significant amount of emissions is from deforestation: see next slide.

Greenhouse gas emissions by economic sectors in 2010

Electricity and Heat Production 25%

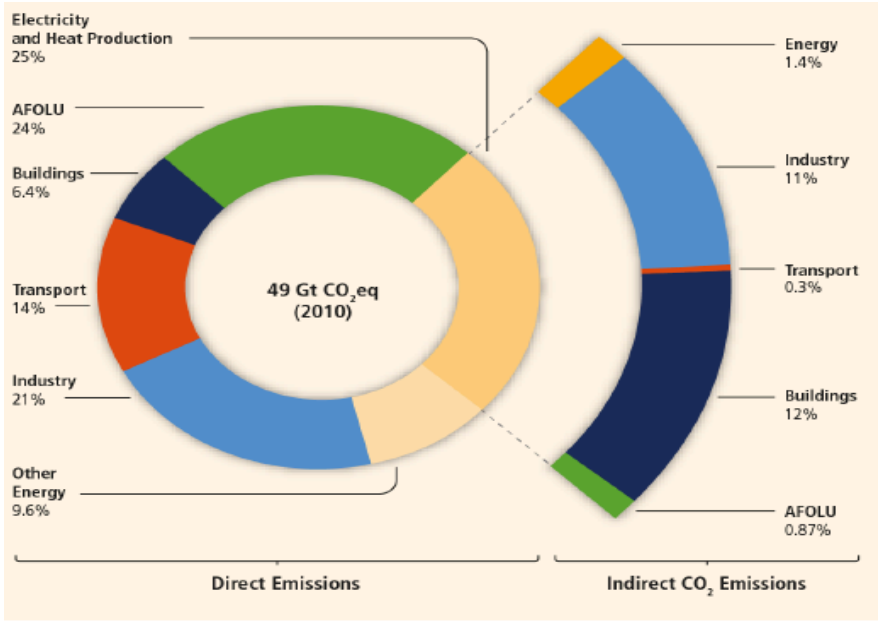
AFOLU 24%

Buildings 6.4%

Transport 14%

Industry 21%

Other energy 9.6%



Energy 1.4%

Industry 11%

Transport 0.3%

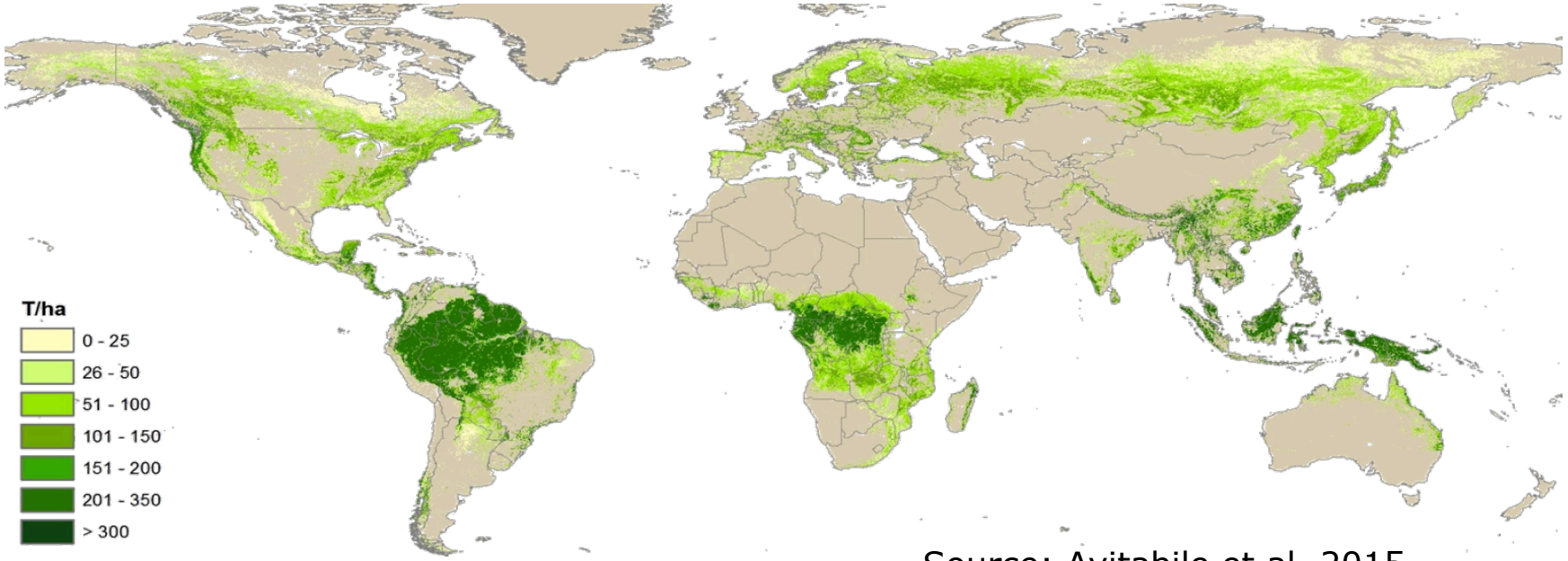
Buildings 12%

AFOLU 0.87%

Source: IPCC, 2014

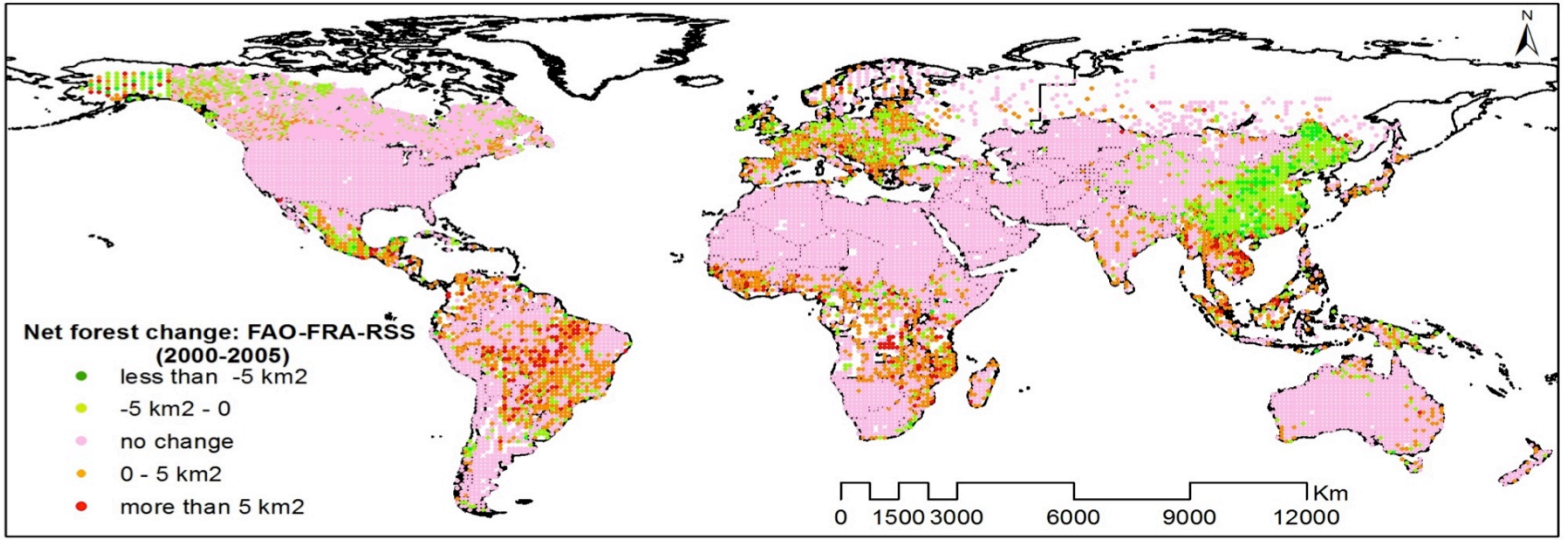
- AFOLU: agriculture, forestry and other land use

Distribution of aboveground forest biomass



Source: Avitabile et al. 2015 (in preparation)

Forest change patterns, 2000–2005



Source: FAO & JRC 2012

Climate mitigation framework REDD+

- United Nations Framework Convention on Climate Change, Cancun Agreements on REDD+ (UNFCCC, 2011. Dec.1/CP16)
  "Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries"

- Following activities are included:
  - Reducing emissions from **deforestation**
  - Reducing emissions from **forest degradation**
  - **Conservation** of forest carbon stocks
  - **Sustainable management** of forest
  - **Enhancement** of forest carbon stocks

REDD

+

Development of REDD+ policy

Conferences of the Parties (COPs)

2005 **COP11 Montreal** RED discussions started. Papua New Guinea and Costa Rica asked for new agenda item: "Reducing emissions from deforestation in developing countries: Approaches to stimulate action."

2007 **COP13 Bali** Bali Action Plan was provided, in which the RED concept was broadened to REDD+.

2009 **COP15 Copenhagen** Methodological guidance for REDD+ activities was developed.

2010 **COP16 Cancun** Cancun Agreements were established, including policy approaches and positive incentives on issues relating to REDD+.

2013 **COP19 Warsaw** REDD+ package was developed, including modalities and guidance for establishing national forest-monitoring systems; measuring, reporting, and verification (MRV); and forest reference (emission) levels and addressing safeguards and drivers.

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1. Introduction to UNFCCC REDD+ process
2. **UNFCCC context and requirements for measurement and reporting of REDD+ activities**
3. IPCC guidelines for national GHG inventories and reporting for forest land
    a. Reporting principles
    b. Estimation of carbon emissions

UNFCCC REDD+ mechanism

- Parties should collectively aim to **slow, halt, and reverse forest cover and carbon loss**, thereby addressing the five REDD+ activities.
- Participation is voluntary and in accordance with respective **capacities and national circumstances**.
- **Performance-based payments** are based on the difference between actual forest emissions and a reference level, which requires:
    - Methodologies to estimate actual emissions and removals
    - Establishment of a reference level with the same coverage of emissions and removals
- REDD+ results-based actions should be **measured, reported, and verified (MRV)**; full implementation requires national monitoring systems.

Guidance from UN climate negotiations on MRV of REDD+ activities

Developing country parties are requested to develop the following elements:

- A national strategy or action plan
    - Including ways to address drivers of deforestation and forest degradation (See Module 1.3) and ensuring safeguards
- A robust and transparent national forest-monitoring system including, if appropriate, subnational systems (See Module 1.2)
- A national forest reference (emission) level (See Module 3.2)
- A system for providing information on the safeguards (respecting the role of local people and ecosystems)

REDD+ phased approach

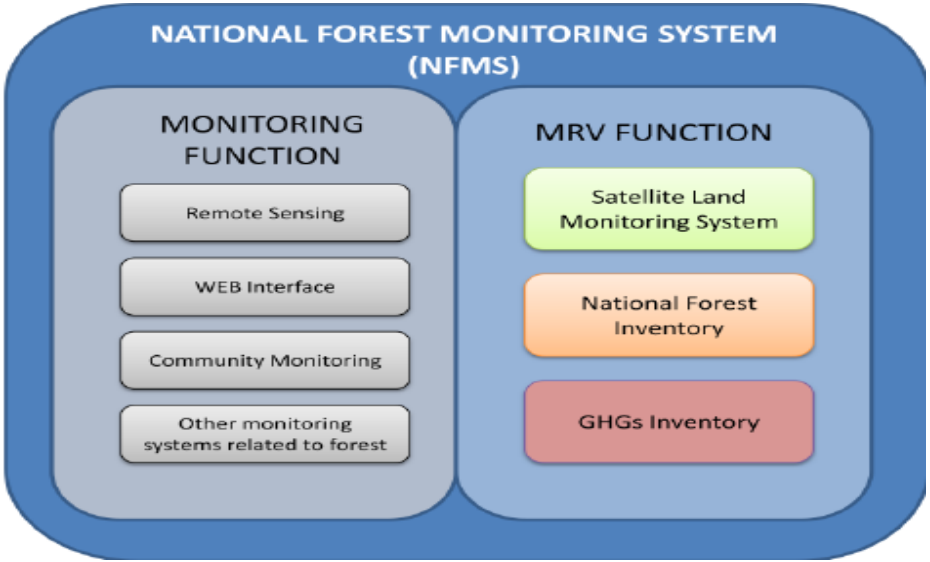
Countries may follow a phased approach for implementing REDD+ in steps, which allows them to gradually build capacities and acquire data

Implementation phase		Characteristics	MRV activities
Phase 1	Readiness	National strategy or action plan formulation, development of policies and measures and capacity building	Capacity-development needs; roadmap development
Phase 2	Transition, implementation, and capacity building	Implementation of national policies and measures and national strategies or action plans (further capacity building); technology development and transfer and results-based demonstration activities	Demonstration activities; monitoring system development
Phase 3	Full implementation	Implementation of national policies and measures on the whole national territory; results-based actions that should be fully measured, reported, and verified	national performance monitoring system; fully operational MRV system to report REDD+ mitigation performance in CO_2e

Modalities for developing national forest-monitoring systems (11/CP.19)

- Countries should establish national forest-monitoring systems (NFMS), with, if appropriate, subnational monitoring and reporting as an interim measure.
- National forest-monitoring systems should:
  - Build on existing systems, as appropriate
  - Enable the assessment of different types of forest in the country, including natural forest
  - Be flexible and allow for improvement
  - Reflect, as appropriate, the phased approach
- For more info on NFMS, see Module 1.2

Concepts of REDD+ MRV and national forest-monitoring systems



Source: UN-REDD 2013

Two simultaneous NFMS functions:

- Monitoring function
  - More than assessment of only carbon
  - Harmonization of existing and new forest-monitoring tools important
  - Should be well harmonized with development of MRV capacities
- MRV function

Modalities for addressing drivers (15/CP.19) & safeguards (12/CP.19)

- Drivers of deforestation and forest degradation (See Module 1.3):
  - It is important to address drivers of deforestation and forest degradation in the context of the development and implementation of national strategies and action plans by developing country parties.
  - Drivers have many causes, and actions to address these drivers are unique to countries' national circumstances, capabilities. and capacities.
- Safeguards:
  - Developing country parties should provide a summary of information on how all of the safeguards referred to in decision 1/CP.16, appendix I, are being addressed and respected throughout the implementation of the activities.

All parties are encouraged to share the summary on safeguards and drivers, including via the web platform on the UNFCCC website.

Modalities for forest reference emission levels (FREL) and forest reference levels (FRL)

- FRLs/FRELs are benchmarks for assessing each country's performance in implementing REDD+ activities. They are:
    - Expressed in t CO_2eq per year
    - Consistent with anthropogenic forest-related GHG emissions and removals from the GHG inventories
- FR(E)Ls should be transparent, taking into account historical data and adjusting for national circumstances.
- FR(E)Ls may be improved over time, incorporating better data, improved methodologies, and / or additional carbon pools.
- Submission of a FR(E)L shall be subject to a technical assessment.
- For more info on FR(E)L development, see Module 3.2.

Modalities for measuring, reporting, and verifying (14/CP.19)

- Results (emissions/reductions) are made in t CO_2 per year, consistent with the assessed reference levels.
- Data and methodologies may be improved over time, while maintaining consistency with FR(E)L.
- Data and information should be provided through biennial update reports by parties that include, in addition to a technical annex:
    - Summary information on assessed FR(E)Ls
    - Results in CO_2eq per year consistent with FR(E)L
    - Methods used for establishing FR(E)Ls and results that are consistent
- A team of Land Use, Land-Use Change, and Forestry (LULUCF) experts will perform a technical analysis of the submitted results.
- For more info on reporting REDD+ performance, see Module 3.3.

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1. Introduction to UNFCCC REDD+ process
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3. **IPCC guidelines for national GHG inventories and reporting for forest land**
    - **a. Reporting principles**
    - b. Estimation of carbon emissions

Reporting of GHG emissions / reductions

- Within UNFCCC REDD+ context, developing countries should:
  - Identify land use, land-use change, and forestry activities and related drivers of deforestation / forest degradation
  - Use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating anthropogenic forest-related GHG emissions and removals, forest carbon stocks, and forest area changes
- Estimating emissions / removals should be done using the IPCC 2003 good practice guidance and guidelines (see next slide)

IPCC Good Practice Guidance and Guidelines

- IPCC guidance and guidelines comes in many different volumes
- Most relevant for REDD+ is 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF), which refers to 1996 Guidelines.
- Countries may wish to refer to the updates in the 2006 Guidelines (AFOLU).
- The GFOI Methods and Guidance Document (MGD) provides systematic linkage between IPCC guidance and each of the REDD+ activities, showing in each case how the IPCC methods can be used to estimate the REDD+ activity and countries may also wish to refer to this.

IPCC good practice principles

Countries should report estimates that are consistent with the five IPCC reporting principles:

- *Consistency* – Same definitions and methodologies used over time
- *Comparability* – *S*tandard methodologies and formats, provided by IPCC and agreed within UNFCCC
- *Transparency* – Assumptions and methodologies clearly explained and appropriately documented
- *Accuracy* – Estimates neither over- nor underestimated, uncertainties reduced as far as is practical
- *Completeness* – Estimates include all agreed categories, gases, and pools for all relevant geographical areas

Forest definitions

- A forest definition is needed to estimate deforestation and other changes.
- Countries may use their own definitions and should use them consistently. UNFCCC asks for an explanation if countries use a different forest definition for REDD+ than the one used for other international reporting.
- FAO forest definition:
    - Minimum forest area: 0.5 ha
    - Trees potential to reach a minimum height of 5 meters
    - Minimum tree crown cover: 10%
    - Forest use should be the predominant land use in the area
- Considerations for establishing forest definition:
    - Thresholds of minimum forest area / crown cover / tree height
    - Including / excluding plantation forests
    - Separate natural forest class

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Estimation of carbon emissions

Carbon emissions Deforestation

$$C_{gr\_em} = \left(\sum_{i=1}^{m} A_{loss(i)} \cdot C_{loss(i)} \right)$$

for forest types i … m

Cgr_em = Gross carbon emissions

Aloss = Area of deforestation (ha), also called *activity data*

Closs = Change in carbon stock per unit area (t/ha), also called *emission factor*

Estimation of carbon emissions

Carbon emissions Deforestation

$$C_{gr\_em} = \left(\sum_{i=1}^{m} A_{loss(i)} \cdot C_{loss(i)} \right)$$

- Data needs:
  - Forest area change (activity data) (See Modules 2.1 and 2.2)
  - Associated carbon stocks changes (emission factors) – See M. 2.3
  - Forests need to be stratified by forest type, e.g., primary forest, modified natural forest, and planted forest (or some other stratification according to national circumstances) (See GFOI MGD for more advice)
- More information on the application of IPCC methods to REDD+ activities and stratification of forests is provided in the GFOI MGD, which describes how to estimate not only deforestation, but degradation and all the other REDD+ activities.

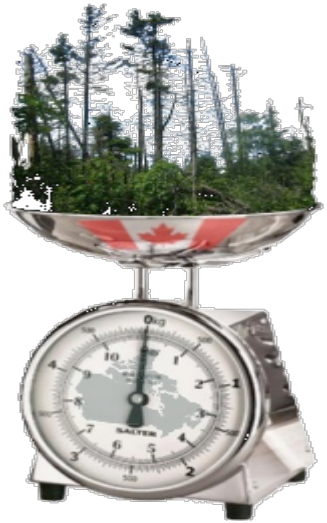
IPCC guidance on assessing activity data

Three approaches for assessing forest area changes, with increasing accuracy and precision

Approach 1	Approach 2	Approach 3
Total area for each land use category, but no information on conversions	Tracking of conversions between land-use categories, on nonspatially explicit basis	Tracking of land-use conversion on a spatially explicit basis
Only net changes between categories	Changes between categories	Changes between categories and within categories

➢ Assessment of remote sensing data (satellite images) for Approach 3

Defining and measuring vegetation biomass



Biomass is defined as mass per unit area of above- or belowground live plant material (in g/m^2 or multiples)

About half of the biomass is carbon (average forest carbon fraction is 0.47)

There are four main ways to estimate biomass:

1. *In situ* destructive direct biomass measurement
2. *In situ* nondestructive biomass estimations (using allometric equations or conversion factors) appropriate to the ecosystem under consideration
3. Inference from remote sensing (can be problems with saturation)
4. Models calibrated to the ecosystem under consideration

See Module 2.3 for more.

IPCC guidance on assessing emission factors

- Emission factor = change in C stock per unit area
- Stratification of carbon stocks into forest types with different C densities
- Assessment of 5 carbon pools per strata:
    - **Aboveground biomass** – trees and shrubs
    - **Belowground biomass** – root biomass
    - **Dead wood** – logs and fallen branches
    - **Litter** – fine woody debris, dead leaves and humus
    - **Soil organic matter** – carbon that has been incorporated into the mineral soil

IPCC guidance on assessing emission factors

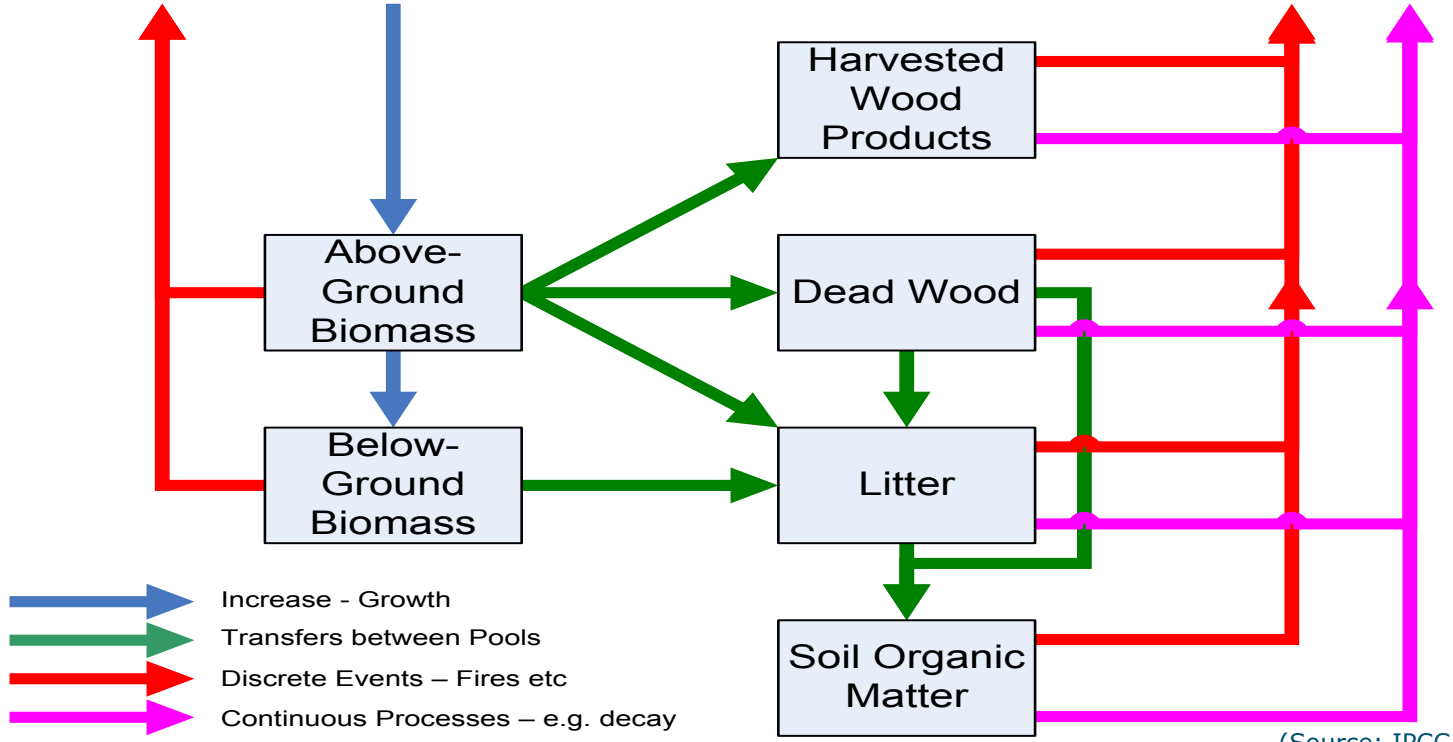
Three tiers for estimating emission factors, with increasing accuracy and precision

Tier 1	Tier 2	Tier 3
IPCC default factors (i.e., biomass in different forest biomes, carbon fraction, etc.)	Country-specific data for key factors (e.g., from field inventories, permanent plots)	Detailed national inventory of key C stocks, repeated measurements of key stocks through time and modeling

Approaches to estimate C emissions

- IPCC describes two methods: gain-loss and stock change.
- Gain-loss is more generally applicable.
- The GFOI MGD describes how to use IPCC guidance to estimate emissions and removals from the five REDD+ activities.
- See Module 2.5 on estimation of carbon emissions from deforestation and forest degradation.

C Pools and fluxes in forests



(Source: IPCC 2003, GPG)

Estimating C emissions from deforestation and forest degradation

- Use of disturbance matrix
- Retention, transfers, and releases of carbon can be tracked
- Impossible transfers are blacked out

From \ To	Above-ground biomass	Below-ground biomass	Dead wood	Litter	Soil organic matter	Harvested wood products	Atmo-sphere	Sum of row (must equal 1)
Aboveground biomass								
Belowground biomass								
Dead wood								
Litter								
Soil organic matter								

Source: IPCC 2006, AFOLU Guidelines

In summary

1. REDD+ is a UNFCCC process following COP decisions.
2. Countries measure and report on the five REDD+ activities and carbon pools defined by IPCC; significant pools and activities should not be omitted.
3. COP decisions require use of IPCC guidance and guidelines.
4. National forest-monitoring systems are needed for measurement, reporting. and verification of REDD+ activities.
5. The GFOI MGD has described how to use IPCC guidance and guidelines to do this.

Country examples and exercises

Country examples

- Review of FCPF country REDD+ readiness preparation proposals
- Phased approach to improving greenhouse gas inventories in Mexico
- Experiences from annex I countries using tier 3 models for carbon accounting

Exercises

- Exercises will start in **Module 1.2.**

Recommended modules as follow-up

- Module 1.2 as a continuation of the UNFCCC context within a country and to learn more about building a national forest-monitoring system for REDD+

- Modules 2.1 to 2.8 to continue with REDD+ measuring and monitoring

- Modules 3.1 to 3.3 to learn more about REDD+ assessment and reporting

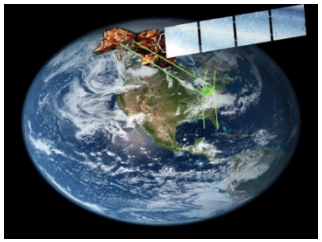
Module 1.2 Framework for building national forest-monitoring systems for REDD+

Module developers:

Erika Romijn, Wageningen University

Martin Herold, Wageningen University

Brice Mora, Wageningen University



After the course the participants should be able to:

- Understand the needs and priorities of a national REDD+ policy and implementation strategy
- Assess and characterize current forest monitoring and reporting capacities taking national circumstances into account

V1, May 2015

Background material

- GOFC-GOLD. 2014. *Sourcebook*. Sections 1 and 4.
- UNFCCC. 2013. Decision 11/CP.19. Modalities for national forest-monitoring systems. http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=31
- UNFCCC. 2010. Decision 1/CP.16. The Cancun Agreements. http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2
- UNFCCC. 2009. Decision 4/CP.15. Methodological guidance for activities related to reducing emissions . . . in developing countries. http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=11
- UN-REDD. 2013. National forest-monitoring Systems: Measurement, Reporting and Verification (M & MRV) in the context of REDD+ Activities.
- GFOI. 2014. Integrating Remote-sensing and Ground-based Observations for Estimation of Emissions and Removals of Greenhouse Gases in Forests: Methods and Guidance from the Global Forest Observation Initiative (MGD). Section 1.4.

Background material

- Hewson, J., Steininger, M., and Pesmajoglou, S., eds. 2013. REDD+ Measurement, Reporting, and Verification (MRV) Manual 2.0: Forest Carbon, Markets and Communities Program. Washington, DC: USAID. http://www.fcmcglobal.org/documents/mrvmanual/MRV_Manual.pdf
- FFPRI. Nov. 2012. REDD+ Cookbook: How to Measure and Monitor Forest Carbon. Tsukuba, Japan: REDD Research and Development Center. http://www.ffpri.affrc.go.jp/redd-rdc/en/reference/cookbook.html
- Herold, M. 2009. An Assessment of National forest-monitoring Capabilities in Tropical Non-Annex I Countries: Recommendations for Capacity Building. Report for the Prince's Rainforests Project and the Government of Norway. Friedrich-Schiller-Universität Jena and GOFC-GOLD. http://princes.3cdn.net/8453c17981d0ae3cc8_q0m6vsqxd.pdf
- UNFCCC. 2009. Cost of Implementing Methodologies and Monitoring Systems. Technical Paper FCCC/TP/2009/1. http://unfccc.int/resource/docs/2009/tp/01.pdf

Outline of lecture

1. UNFCCC requirements for national forest-monitoring systems (NFMS) and measurement, reporting, and verification (MRV) of REDD+ activities
2. Framework for NFMS
3. Building technical and institutional capacity for NFMS and REDD+ MRV
4. Planning and implementing a NFMS for REDD+ MRV
5. Cost implications and different factors contributing to the costs

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National forest-monitoring systems and MRV

- REDD+ results-based actions should be fully **measured, reported, and verified**.
- **Forest reference emissions levels** and **forest reference levels** are benchmarks for assessing performance in implementing REDD+ activities and need to be consistent with historical data in greenhouse gas (GHG) inventories
- Countries need to set up a **robust and transparent national forest-monitoring system** to estimate emissions and establish a reference level which will be subject to technical assessment in the context of results-based payments

Modalities for national forest-monitoring systems

Full implementation of results-based actions requires national forest-monitoring systems (UNFCCC 2014, 11/CP.19).

National forest-monitoring systems, with, if appropriate, subnational monitoring and reporting as an interim measure, should:

- Build upon existing systems, as appropriate
- Enable the assessment of different types of forest in the country, including natural forest
- Be flexible and allow for improvement
- Reflect, as appropriate, the phased approach

Methodological guidance from UNFCCC

National forest-monitoring systems should:

- Use a combination of remote sensing and ground-based forest carbon inventory approaches
- Provide estimates that are transparent, consistent, and, as far as possible accurate and that reduce uncertainties, taking into account national capabilities and capacities
- Be transparent and the results should be available and suitable for review

UNFCCC (2009, 4/CP.15) methodological guidance for REDD+

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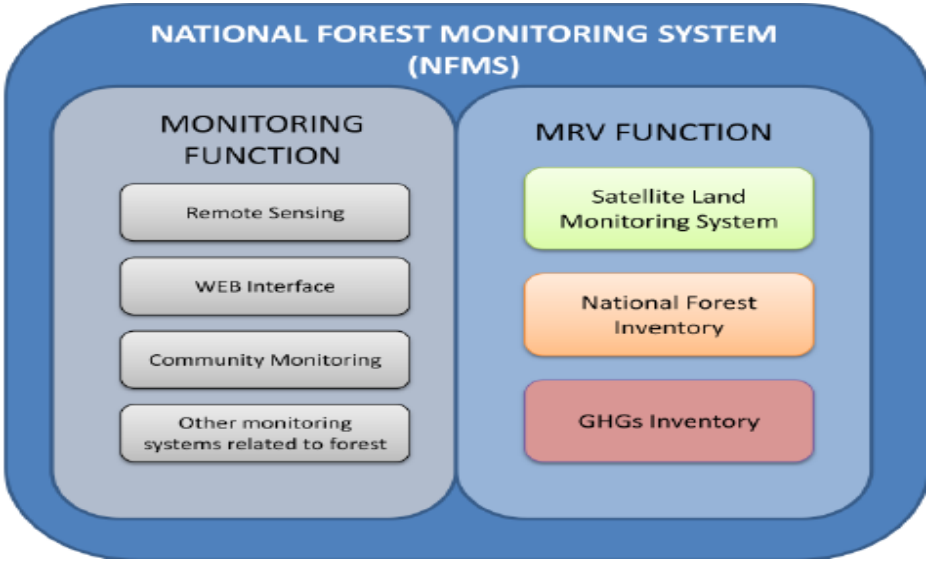
Link between REDD+ MRV and national forest-monitoring systems



Source: UN-REDD, 2013.

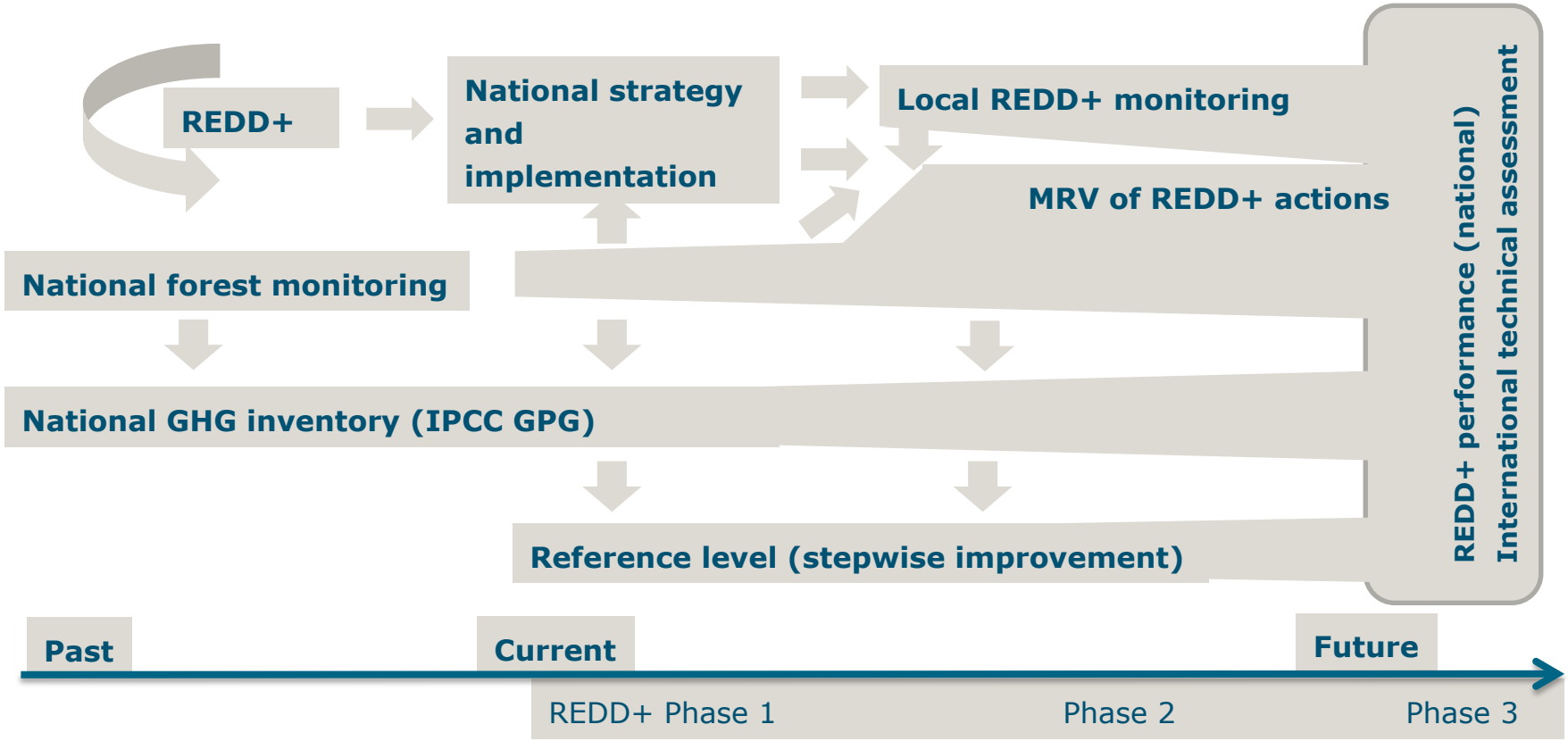
2 simultaneous functions of NFMS:

- **Monitoring function**
  - More than assessment of only carbon
  - Harmonization of existing and new forest-monitoring tools important
  - Should be well harmonized with development of MRV capacities
- **MRV function**

Multiple benefits of a national forest-monitoring system (NFMS)

1. Address domestic and international monitoring needs:
    - Keep track of a country's forest resources—forest area, number of trees planted, ecosystem types, etc.
    - Monitor water resources and quality
    - Monitor biodiversity conservation
    - Monitor land rights / use NFMS for land tenure
2. Assess countries REDD+ policies and measures:
    - MRV for REDD+: MRV is only one part of a national forest-monitoring system!

Framework for national REDD+ monitoring



Use of remote sensing within the NFMS

- Requirements for estimating forest emissions in the context of REDD+:
  - Historical data on forest area changes and changes in forest carbon pools, consistent with IPCC guidance and Conference of the Parties (COP) decisions
    → Needed to establish forest reference emission levels and to estimate forest GHG emissions and reductions
  - Understanding of deforestation processes and drivers
- Use of remote sensing for REDD+ measurements:
  - Provides primary source of data to measure forest area changes
  - Provides indicators for areas affected by forest degradation
  - Forest area change maps can be linked to specific activities of deforestation (follow-up land use), which are useful for assessing drivers

Technical challenges for the use of remote sensing

Factor	Challenges	Potential solutions
Mean annual cloud cover	Annual cloud cover probability varies from <10% to >90% cover between countries. With optical imagery, it is not possible to take measurements through clouds.	- Optical data: combination of multiple sensors enhancing artificially revisited time period (e.g. Landsat, Sentinel-2) - Use of synthetic aperture radar (SAR) data: not constrained by cloud cover - Use of data fusion methods (Optical+SAR)
Seasonality	Variability in cloud cover during the year in tropical Non-Annex I countries	Increase frequency of satellite images (higher satellite revisit time period) to increase chance to obtain optical observations at appropriate periods (e.g., upcoming Sentinel-2 constellation)
Topography	Variations in altitude in mountainous regions cause topographic effects in satellite images, making it difficult to analyze the remote sensing signal	Use of adequate orthorectification procedures available in some image processing software (e.g., ENVI, Idrisi, ERDAS, PCI Geomatics), requires the use of digital elevation models (DEMs)
Average Internet download speed	Problems / delays to regularly download large image datasets	Use CD ROMs, external hard drives to disseminate data and products, externalize data processing, foster regional approaches, i.e., cross-country coordination, use of networks (GOFC-GOLD, FAO, etc.)

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Requirements for NFMS and building capacity

- Requirements at national level:
  - International: Requirements of COP decisions on MRV, including consistency with the IPCC Good Practice Guidance (GPG)*
  - National: Needs and priorities of the national REDD+ policy and implementation strategy
- Bridging the capacity gap:
  - Assessment of existing national forest-monitoring technical capabilities versus the requirements for the MRV system
  - Develop and implement a roadmap: to build sustained in-country capacities for MRV based on international requirements and national needs to implement REDD+ policy

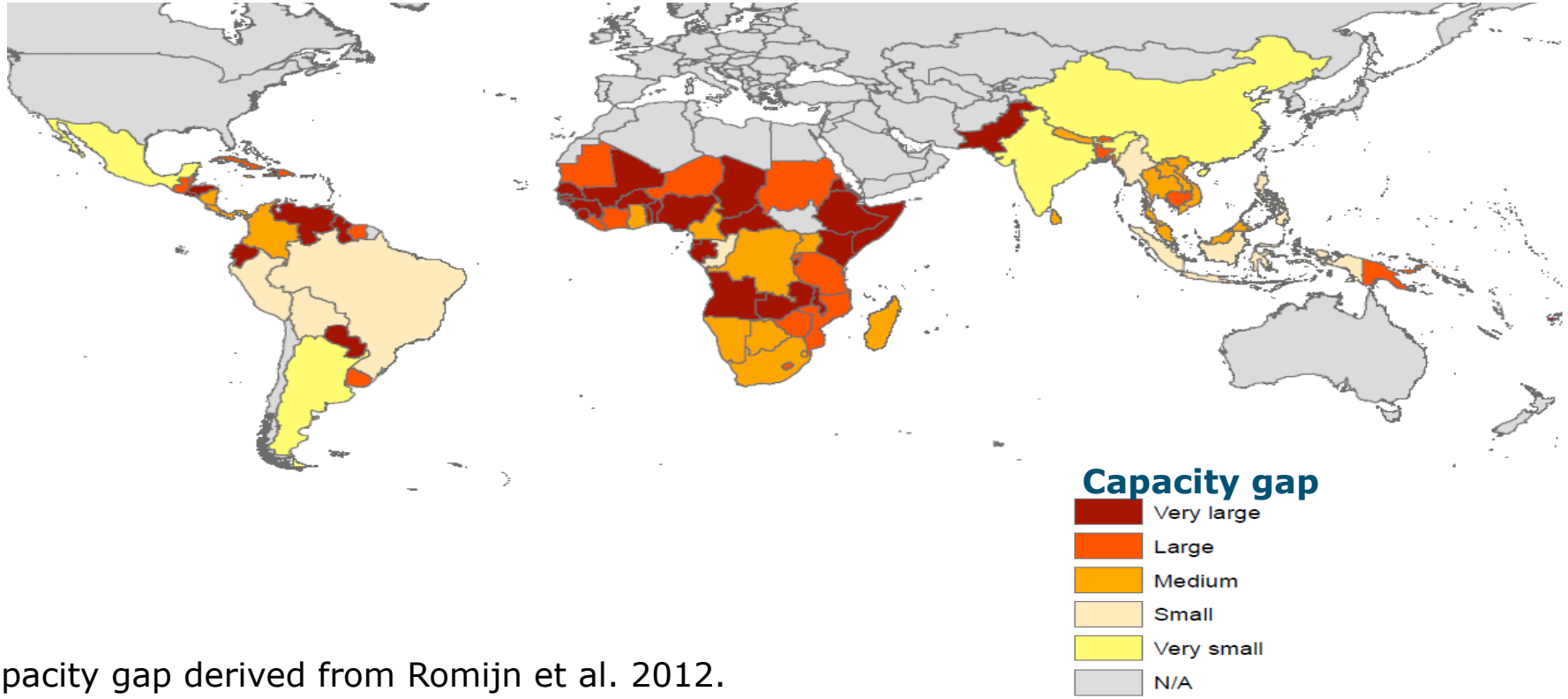
* For information on using the IPCC GPG and Guidelines in the REDD+ context, see Module 1.1 and GFOI MGD.

Assessment of existing national forest-monitoring technical capabilities versus the requirements for the MRV system

Consideration of factors:

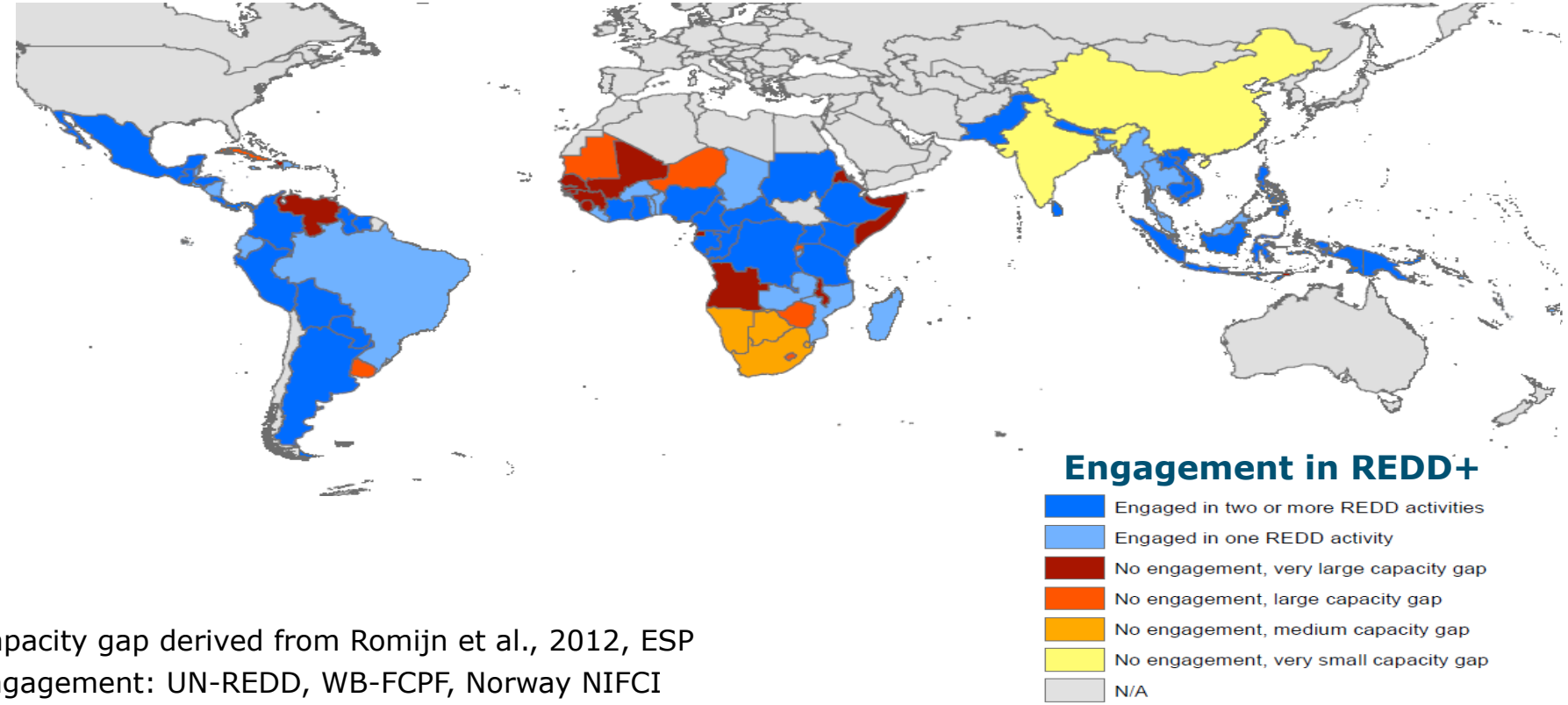
1. Requirements for monitoring forest carbon at the national level (IPCC GPG)
2. Existing national capacities for national forest monitoring
3. Progress in national GHG inventory to estimate GHG associated with REDD+ activities (GFOI MGD describes how to do this)
4. REDD+ particular characteristics: importance of forest fires, soil carbon, deforestation rate, etc.
5. Specific technical challenges (remote sensing): cloud cover, seasonality, topography, remote sensing data availability, and access procedures

REDD+ monitoring capacities



Capacity gap derived from Romijn et al. 2012.

REDD+ monitoring capacities vs. engagement



Capacity gap derived from Romijn et al., 2012, ESP
Engagement: UN-REDD, WB-FCPF, Norway NIFCI

Building technical and institutional capacity

- Technology transfers from developed countries are encouraged.
- Building technical and institutional capacity for NFMS should take into account:
  - National circumstances (forest types, institutional arrangements, economy, culture)
  - Drivers of deforestation (see Module 1.3)
  - Existing capacities

Capacity improvements for NFMS through REDD+ phased approach

NFMS can be implemented starting at phase 1 and moving toward phase 3 of REDD+, with step-by-step improvements

Implementation phase		Characteristics	MRV activities
Phase 1	Readiness	National strategy or action plan formulation; development of policies and measures and capacity building	Capacity-development needs assessment; develop roadmap development
Phase 2	Transition, implementation, and capacity building	Implementation of national policies and measures and national strategies or action plans (further capacity building); technology development and transfer and results-based demonstration activities	Demonstration activities; monitoring system development
Phase 3	Full implementation	Implementation of national policies and measures on the entire national territory; results-based actions that should be fully measured, reported, and verified	National performance- monitoring system; fully operational MRV system to report REDD+ mitigation performance in CO_2e

MRV coordination on different levels

- **International support:**
  - South-South cooperation
  - Donors and supporting agencies/organizations
  - Technical community providing guidance
- **National strategy and MRV development:**
  - MRV roadmap and policy priorities
  - Institutional setup and multisector partnerships
  - Maximize country benefits from multidonor support
- **Subnational implementation:**
  - Stakeholder involvement in MRV
  - Linking national and local monitoring and verification

Institutional framework

- Create **Strong institutional set up** as enabling framework.
- Establish and maintain **partnership and cooperation** on all levels.
- **Coordinate and integrate** national datasets through a high-level national technical committee.
- Develop **national data management** system and infrastructure.

→ See Module 3.1

- Sustain internal and national **communication mechanisms.**
- Involve all relevant **national stakeholders** involved in MRV and REDD implementation and mechanisms to ensure transparent and open exchange and management of data streams.
- Engage with **local and international community**.
- Clarify **roles and responsibilities**.

Institutional capacity development

- A suitable degree of **organizational capacity** within the country is required to establish and operate a national forest-monitoring system for REDD+.
- Consider establishing and maintaining the following **institutions** with clear definition of roles and responsibilities:
  - A national coordination and steering body or advisory board, including a national carbon registry
  - A central carbon monitoring, estimation, reporting, and verification authority, including forest carbon measurement units
- Consider building a link to subnational implementation activities and benefit sharing mechanisms.

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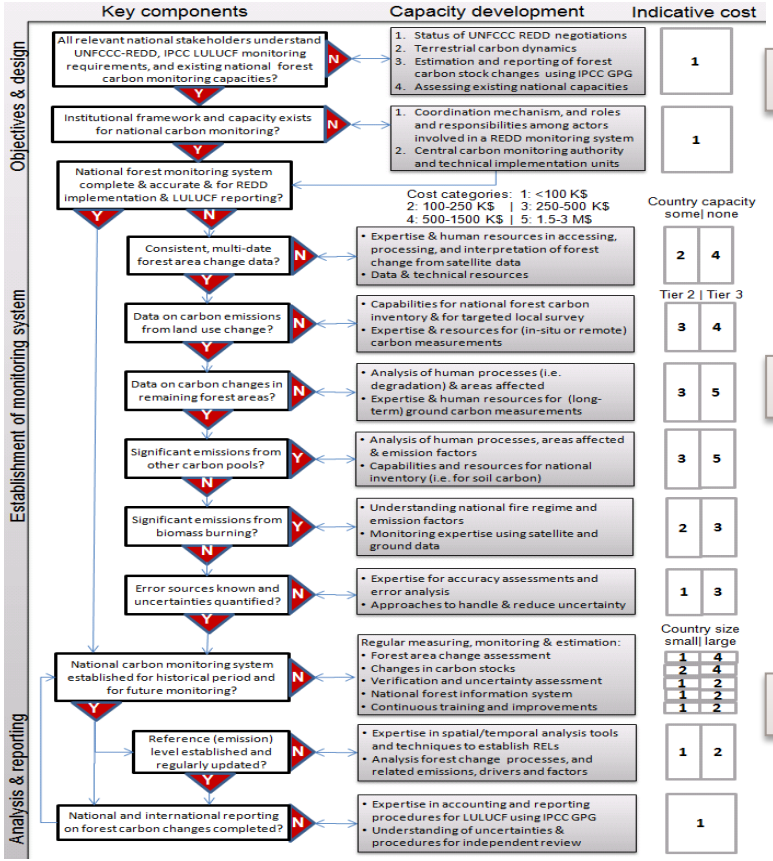
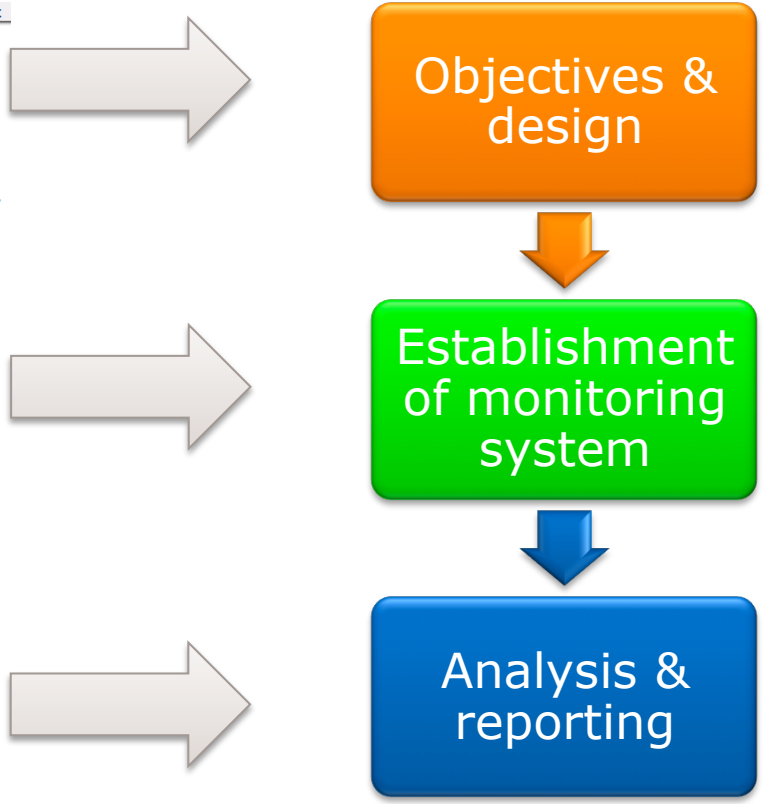
Planning and implementation of REDD+ MRV

1. Define initial priorities for capacity development:
    - Understanding the national REDD+ implementation strategies and policies
    - Identifying high priority areas to focus MRV activities (and demonstrations) using a stratified national approach
2. Early actions may be subnational, but leakage needs to be assessed nationally.
3. Synergy of national and local monitoring and ensurance that REDD+ safeguards are in place:
    - Role of local communities and how to engage national expertise in REDD+ implementation (See Module 2.4)
    - Possible links with monitoring of biodiversity or co-benefits in general
4. Link with development of benefit-sharing mechanisms.

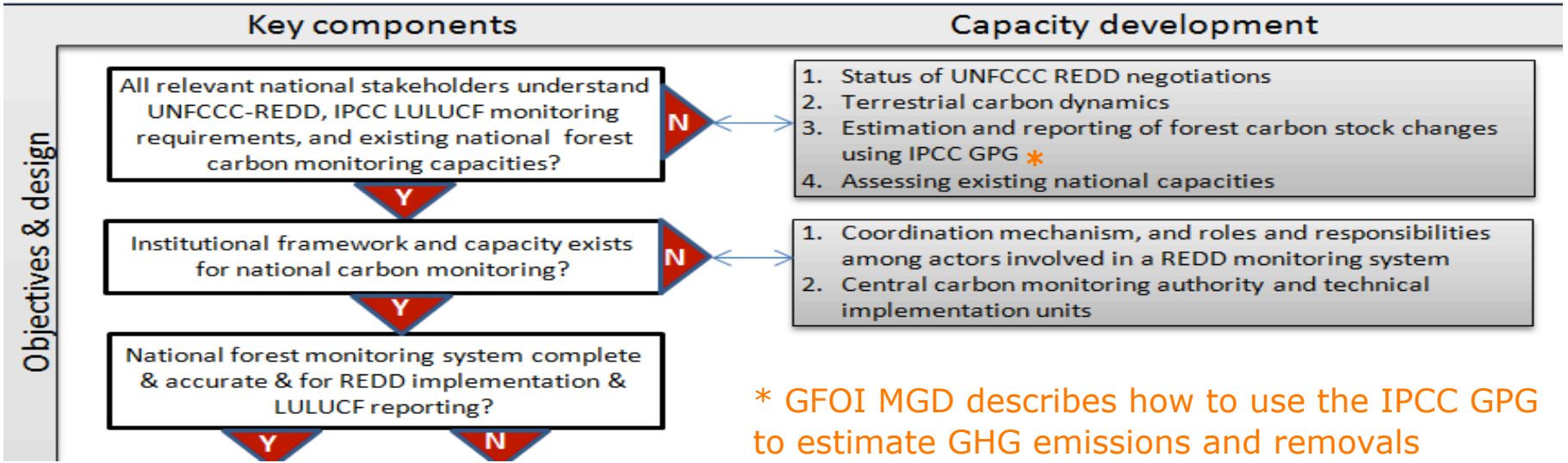
Process for establishing a national monitoring system





Source: GOFC-GOLD Sourcebook 2014, figure 4.2.5.

Objectives and design



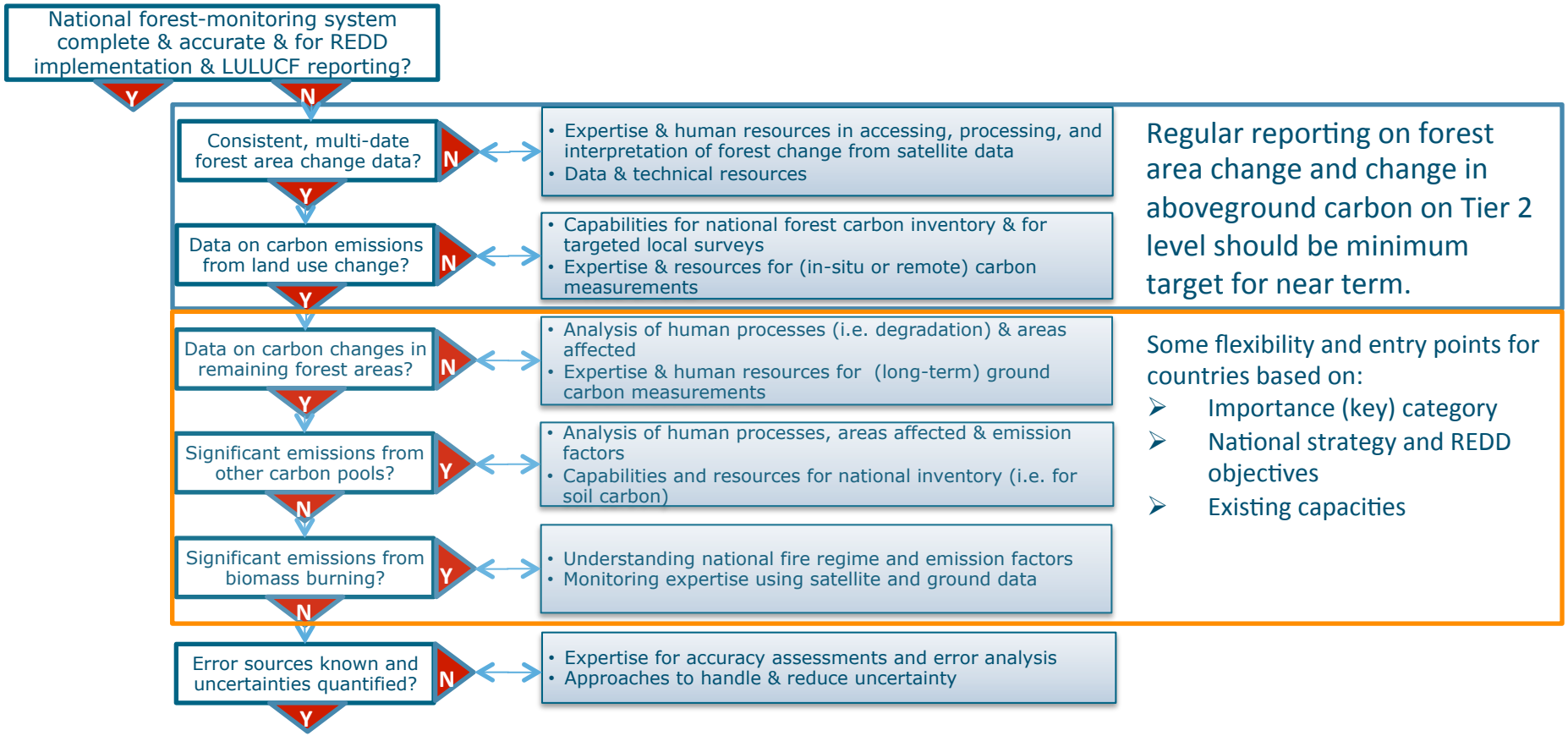
* GFOI MGD describes how to use the IPCC GPG to estimate GHG emissions and removals associated with REDD+ activities

Objectives and design phase of NFMS

Objectives and design:

- Should result in a national **monitoring framework** that includes elements, such as definitions, monitoring variables, and an institutional framework
- Should result in a **plan for capacity development** and long-term improvement of the system and estimation of the costs of establishing such a system
- Requires **resources** for **training and capacity building**, for participating in / organizing dedicated national or regional workshops, and for expert support

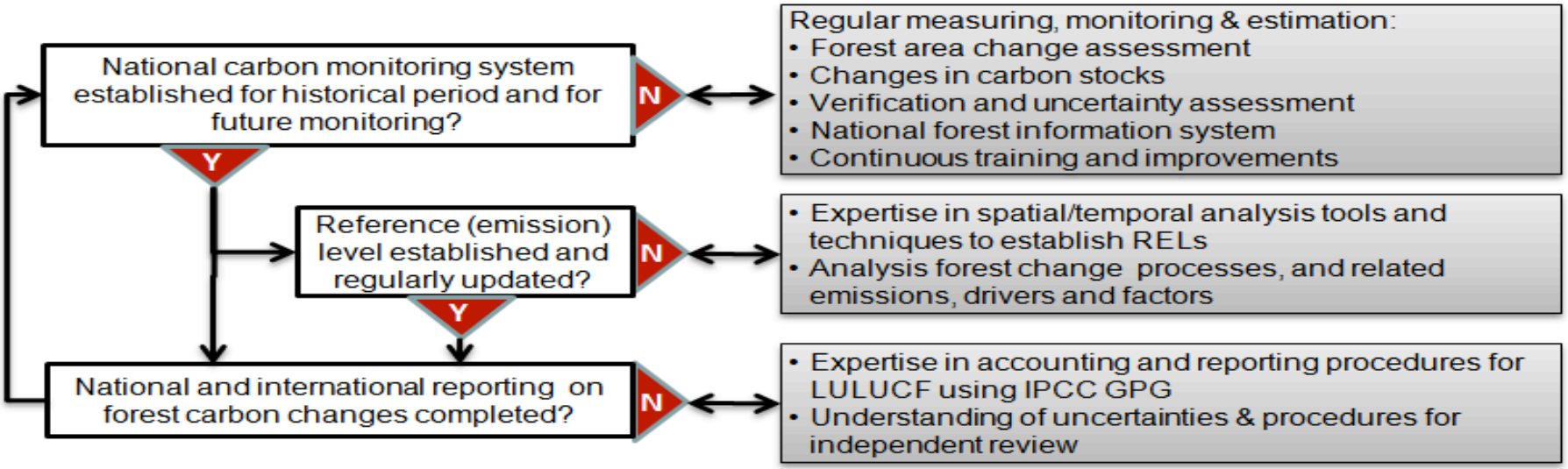
Establishment of monitoring system



Monitoring in establishment phase

- Assess and make best use of **existing observations and information**.
- Specify a methodology and operational implementation framework for **monitoring forest area change** on a national level.
- Perform analysis of historical satellite data for establishing forest **reference emission levels** or forest reference levels.
- Develop understanding of areas affected by **forest degradation** and provide assessment on how to monitor relevant forest degradation processes.
- Complete **recruitment** and provide **training** to national team to perform monitoring activities.
- Complete an **accuracy and error analysis** for estimates from the historical period.
- Perform **a test run** of the operational forest area change monitoring system.

Analysis and reporting



Example: REDD+ MRV roadmap for Ethiopia

1. Establish institutional arrangements.
2. Improve national forest-monitoring: activity data.
3. Improve national forest monitoring: carbon stocks and emission factors.
4. Improve estimation and international LULUCF, GHG inventory, and REDD+ reporting capacities.
5. Prepare for MRV of REDD+ activities on the national level.
6. Implement a program for continuous improvement and capacity development.
7. Continued national and local communication mechanism on REDD+ monitoring

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Cost implications of an NFMS

- Several categories of costs, including **opportunity costs** and costs for **transactions** and **implementation**
- MRV of forest carbon primarily reflected in transaction costs:
  - Proof that a REDD+ activity has indeed achieved a certain amount of emission reductions
- Resources needed for monitoring relatively small compared to all cost factors for REDD+ implementation in the long-term:
  - May be rather significant in the country readiness phase since many countries require the development of basic capacities

Costs for remote sensing

Implementation of a satellite-based monitoring system includes a number of cost factors:

- Satellite data, including data access and processing
- Software, hardware, and office resources, including satellite data archive
- Human resources for data interpretation and analysis
- Monitoring in readiness phase
- Operational monitoring
- Accuracy assessment
- Regional cooperation for capacity building and technical assistance

Utility of optical sensors at multiple resolutions for deforestation monitoring

Sensor and resolution	Examples of current sensors	Minimum mapping unit (change)	Cost	Utility for monitoring
Coarse (250–1000 m)	SPOT-VGT (1998–) Terra-MODIS (2000–) Envisat-MERIS (2004– 2012) VIIRS (2012–)	~ 100 ha ~ 10–20 ha	Low or free	Consistent pan-tropical annual monitoring to identify large clearings and locate "hotspots" for further analysis with mid resolution
Medium (10–60 m)	Landsat TM or ETM+, Terra-ASTER IRS AWiFs or LISS III CBERS HRCCD DMC SPOT HRV ALOS AVNIR-2	0.5–5.0 ha	Landsat & CBERS are free. For others: <$0.001/km² for historical data, $0.02/km² to $0.5/km² for recent data	Primary tool to map deforestation and estimate area change
Fine (<5 m)	RapidEye IKONOS QuickBird GeoEye WorldView Pleiades Aerial photos	< 0.1 ha	High to very high $2–30 per km²	Validation of results from coarser resolution analysis, and training of algorithms

Source: GOFC-GOLD Sourcebook 2014, table 2.1.1.

Anticipated core optical missions with freely available data

Agency	Mission	Launch	Resolution	Swath	Revisit	Planned Duration
USGS/NASA	Landsat-7	1999	15m, 30m	185 km	16 days	5 years
USGS/NASA	Landsat-8	2013	15m, 30m	185 km	16 days	5 years
INPE/ CRESDA	CBERS-4	2015	5m 10m, 20m, 40m, 64m	60-866 km	26 days	3 years
ESA	Sentinel 2A	2014	10m, 20m, 60m	290 km	10 days	7 years
ESA	Sentinel 2B	2015	10m, 20m, 60m	290 km	10 days	7 years

CEOS Missions, Instruments and Measurements database
See http://database.eohandbook.com

Source:
CEOS 2015.

See also GFOI MGD, annex B.

Anticipated core synthetic aperture radar (SAR) missions with freely available data

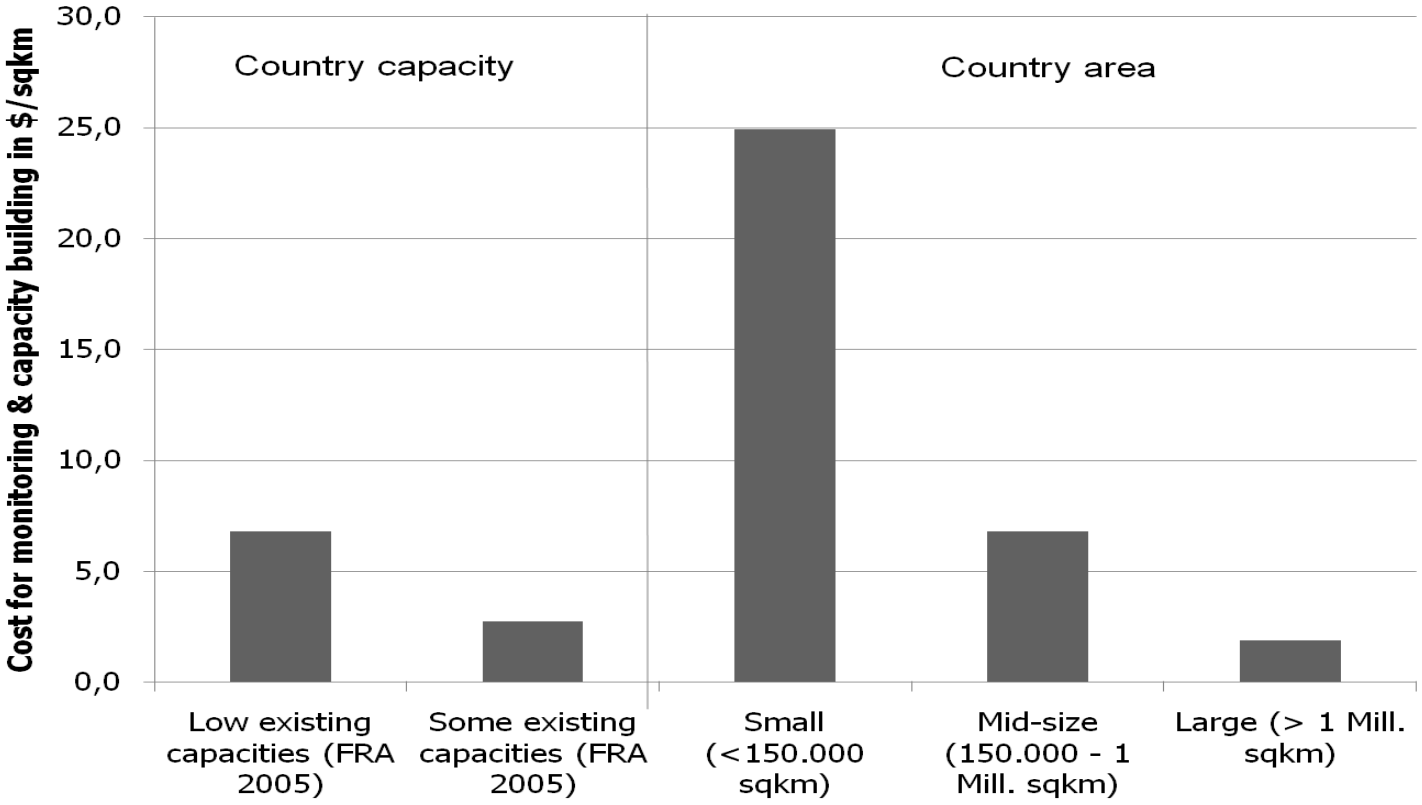
Agency	Mission	Launch	Band (wave length)	Polarization	Resolution	Revisit	Duration
ESA	Sentinel-1A and 1B	2014 and 2015	C (5.6 cm)	Single-, Dual-polarisation	9 m, 20 m, 50 m	12 days	7 years
CSA	RADARSAT Constellation Mission (3 satellites)	2018	C (5.6 cm)	Single-, Dual-, Full-polarisation	1 m, 3 m, 5 m, 16 m, 50 m, 100 m	12 days	7 years
CONAE/ ASI	SAOCOM-1A and 1B	2015 and 2016	L (23.5 cm)	Single-, Dual-, Full-polarisation	10 m, 30 m, 50 m, 100 m	16 days	5 years

CEOS Missions, Instruments and Measurements database
See http://database.eohandbook.com

Source:
CEOS 2015.

See also:
GFOI MGD, annex B.

Cost for monitoring & capacity building



Source: GOFC-GOLD Sourcebook 2014, figure 4.3.1.

In summary

1. Establishing a national forest-monitoring system is essential for measurement, reporting, and verification (MRV) of REDD+ activities.
2. There are different elements of a national forest-monitoring system: monitoring function and MRV function.
3. A strong institutional framework is important.
4. A roadmap is needed for building sustained in-country capacities for MRV along the three REDD+ implementation phases.
5. Thee are different factors contributing to the costs of establishing and operating a national forest-monitoring system—monitoring costs may be significant, especially in the start-up phase.

Country examples and exercises

Country examples

- UN-REDD monitoring framework for Democratic Republic of Congo
- Establishment of a system for monitoring, reporting and verification of REDD+ in Guyana

Exercise

- Assessing national forest-monitoring and reporting capacities
    1. Assessing forest-monitoring and reporting capacities for a few selected countries, based on FAO Forest Resources Assessment reports
    2. Assessing monitoring capacity and REDD+ and remote sensing (technical) challenges in your own country

Recommended modules as follow-up

- Module 1.3 for considering national circumstances within a national forest-monitoring system and assessing and analyzing drivers of deforestation and forest degradation

- Modules 2.1 to 2.8 to continue with REDD+ measuring and monitoring

- Modules 3.1 to 3.3 to learn more about REDD+ assessment and reporting

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Thank You

Next Week:

Sensors and products available for terrestrial ecosystems