WWF GUIDE TO BUILDING REDD+ STRATEGIES

Tracking REDD+

MONITORING, MEASUREMENT, REPORTING AND VERIFICATION

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Key Messages

- Forest monitoring, measurement, reporting and verification (MMRV) systems are the backbone of a performance-based system for REDD+. For this reason, they are vital to a national or subnational REDD+ strategy, and should track information in a way that is consistent, complete, transparent and comparable with known estimated accuracies.
- MMRV systems should adhere to the latest Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance for Land Use, Land-Use Change and Forestry; and IPCC Guidelines for National Greenhouse Gas Inventories. MMRV systems should aim to develop geographically explicit land use data (IPCC Approach 3) using emissions estimates that use at least IPCC Tier 2 reporting standards.
- Forest monitoring systems will need a combination of both remote-sensing and field data. As field measurements are both costly and time consuming, strategic selection of field sites through stratification and sampling will be important.

INTRODUCTION

Monitoring, measuring, reporting and verification (MMRV) systems can be broken down into four major components: forest monitoring (M1), measurement (M2), reporting systems (R) and verification (V). These concepts are frequently, and often confusingly, interchanged, and their difference is seldom elaborated. Here we will show how these systems differ and how together they constitute the backbone of REDD+ implementation by providing a resource tracking and inventory system of land use and land-use change and their related emissions. Throughout this chapter we will refer to the three different systems outlined below:

WEBINAR VIDEO: MRV—WHAT DO YOU NEED TO KNOW TO MAKE THE RIGHT DECISION?
LEARNING SESSION 3

WEBINAR VIDEO: ASSESSING ACCURACY AND ESTIMATING AREA OF REMOTELY SENSED CHANGE MAPS
LEARNING SESSION 11

Forest monitoring (M1) systems are the physical and technological systems that are used to generate forest-cover data and detect and quantify changes observed in forest cover (including above- and below-ground biomass, forest types, canopy density, etc.). The information that we collect in our forest monitoring systems are the primary data source and are therefore critical for the overall accuracy and precision of our MMRV system. As such, forest monitoring systems need to be comprehensive enough to allow the tracking of all forests in a country as well as sensitive enough to be able to detect forest presence/absence according to the country's forest definition.

Measurement (M2), Reporting and Verification (M2RV) systems in contrast are a combined set of methodologies and standards that we use to translate our primary data into measurable and reportable emissions estimates that are verifiable by an external entity or authority. For much of the purpose of this document the external institution that we are reporting to will be the United Nations Framework Convention on Climate Change (UNFCCC); however, we might also develop M2RVsystems under other third-party entities such as the Verified Carbon Standard (VCS); the Climate, Community and Biodiversity Alliance (CCBA) or the American Carbon Registry (ACR).

Monitoring, measurement, reporting and verification (MMRV) is the combination of the two above systems, with the purpose to track changes in forest areas in a way that is transparent, consistent, accurate and reduces uncertainties. This is critical if we are to establish whether or not our interventions are having positive or negative effects in forest ecosystems over time.

MMRV systems are often discussed in the context of climate change, and therefore measuring greenhouse gas (GHG) emissions will be important. They can also help track a range of other indicators (e.g. biodiversity, hydrology, cultural values). Throughout this chapter we will predominantly be discussing GHG emissions MMRV systems, recognizing that developing MMRV systems across a range of indicators will improve both the efficiency and effectiveness of our tracking systems.

INTERNATIONAL POLICY CONTEXT

There are several international standard-setting bodies for MMRV. The most important of these is the UNFCCC since it sets the international legal, regulatory and institutional framework for forest owning countries to monitor, measure and report on their forests. Other systems include VCS and CCBA, which to a greater or lesser extent influence developing country MMRV systems. The following section will summarize the major decisions that have been made under the UNFCCC and where relevant in other arenas that guide the national and subnational context for MMRV.

COP 13: Bali, 2007

The UNFCCC has provided guidance on MMRV dating back to the UNFCC 13th Conference of the Parties (COP 13) in Bali in 2007. The Bali Decision requested that parties improve their **data collection**, **estimation of emissions** from deforestation and forest degradation and **monitoring and reporting** capabilities.[1] It was also agreed that parties should use their national GHG inventories as a basis for reporting emissions from deforestation, noting also that developing country parties should use the IPCC Good Practice Guidance (GPG) for Land Use, Land-Use Change and Forestry (LULUCF)[2] and IPCC Guidelines for National GHG inventories (see *Focus*).

COP 15: Copenhagen, 2009

In 2009, at COP 15 in Copenhagen, developing countries were asked to establish robust and transparent **national forest monitoring systems**[3] that use a combination of **remote sensing** and **ground-based** forest carbon inventory approaches for estimating emissions, removals, forest carbon stocks and forest area changes; and for providing estimates that are **transparent**, **consistent**, **accurate**, and **reduce uncertainties**.[4]

COP 16: Cancun, 2010

In 2010, at COP 16 in Cancun further guidance was given on ways to integrate subnational monitoring systems into national monitoring systems, including provisions for reporting on how displacement of emissions is being addressed.[5] Importantly Cancun created a roadmap for parties to discuss forest monitoring systems and MRV systems (MMRV) with an agreement scheduled for COP 17 in Durban.

COP 17: Durban, 2011

In 2011, at COP 17 in Durban, parties failed to come to an agreement on the modalities for forest monitoring and MRV. Parties continued discussing these issues at Bonn in May 2012, and their positions are captured in draft text[6] that provides guidelines on both forest monitoring systems and MRV systems.

The draft text states that national **forest monitoring systems** should provide data that is *transparent*, *consistent over time* and *complete*.[7] Data should also build upon existing systems, provide information on all forest areas in the country, enable the assessment of changes incurred in natural forests, be flexible and allow for improvement, and identify potential sources of uncertainties to the extent possible. The draft text also states that forest monitoring systems can provide information on safeguards.

The draft text also agrees that **MRV systems** should provide data and information on anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes that are *transparent*, *complete* and *consistent* with the established forest reference level and, over time, are *accurate* and *comparable*. In addition, it states that MRV systems can be improved over time. The draft text also sends an important signal that all data for REDD+ reporting should be provided through biennial update reports (BURs).[8] These reports should contain information on GHG emissions and removals, nationally appropriate mitigation actions (NAMAs), and any financing, technology and capacity-building gaps. This information will be submitted using UNFCCC guidelines for the preparation of national communications (Decision 17/CP.8) as well as adhere to IPCC GPG for LULUCF. In Durban it was also agreed that developing countries should verify their emissions using a process called International Consultation and Analysis (ICA). The ICA process will consist of two steps:

- A *technical analysis* of BURs by a team of technical experts in consultation with the party to UNFCCC, resulting in a summary report. The information considered should include the national GHG inventory report along with NAMAs, including their impacts and progress made in their implementation.
- A *facilitative sharing of views*, which will have as input the BUR and summary report referred to above.

NATIONAL AND SUBNATIONAL OPTIONS

MMRV systems can be implemented in many ways. As mentioned before, these systems must be *transparent*, *consistent*, *accurate*, *comparable* and *reduce uncertainties*. While MMRV systems can track a range of variables, at a minimum they must provide information on how much CO_2 is being emitted or sequestered as a result of current management practices. In order to build up this information, MMRV systems first need to answer two fundamental questions:

- What is the rate of change of forest area and forest type (activity data)?
- What are the emissions related to that change (emissions factors)?

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IPCC GUIDELINES FOR NATIONAL GHG INVENTORIES (2006) AND IPCC GOOD PRACTICE GUIDANCE FOR LULUCF (2003)

The following is adapted from these reports

The IPCC Guidelines for National GHG Inventories (2006) (hereafter 'Guidelines') and the Good Practice Guidance for LULUCF (hereafter 'GPG') assist countries in compiling complete, national inventories of greenhouse gases. The Guidelines have been structured so that any country should be able to produce reliable estimates of their emissions by sources and removals by sinks across all sectors. Combined, these resources provide the backbone for reporting methodologies under the UNFCCC.

Both the Guidelines and the GPG support a tiered and tailored reporting approach for measuring emissions in the Agriculture, Forestry and Land Use (AFOLU) sector, allowing for different levels of technical capacity across countries. In general, moving to a higher tier improves the accuracy of reporting and reduces the uncertainty, but the complexity and resources required for conducting inventories also increase for higher tiers. If needed, a combination of tiers can be used (e.g. Tier 2 can be used for biomass and Tier 1 for soil carbon).

Tier 1 methods are designed to be the simplest to use. Under Tier 1 accounting, default equations and values (e.g. emission and stock change factors) are used. Country-specific activity data is needed, but for Tier 1 there are often globally available sources of activity data estimates (e.g. deforestation rates). This data is usually spatially coarse.

Tier 2 can use the same methodological approach as Tier 1 but applies emission and stock change factors that are based on country- or region-specific data. Higher temporal and spatial resolution and more disaggregated activity data are typically used in Tier 2.

Tier 3 uses higher-order methods and higher resolution activity data disaggregated at the subnational level. These higher-order methods provide estimates of greater certainty than do lower tiers. Such systems may include comprehensive field sampling repeated at regular time intervals and/or GIS-based systems. Models should undergo quality checks, audits and validations, and be thoroughly documented.

The system will also allow/help address the following questions:

- What types of forests does the country currently have?
- What are the main direct drivers of deforestation?
- What is the level of uncertainty with our measurements?
- How are other indicators (e.g. biodiversity) changing over time?

The following sections will show how these questions are addressed under the four components of MMRV:

- M_1: Forest monitoring
- M_2: Measurement
- R: Reporting
- V: Verifying

Forest monitoring systems (M_1)

There are two primary ways in which data needs to be gathered for forest monitoring systems:

- *Indirectly* using **remote sensing technologies** (e.g. satellite or airborne detectors) and other ancillary data (e.g. maps, historical records)
- *Directly* using crews on the ground to collect **field data**.

As discussed in the introduction, most, if not all, forest monitoring systems will use a combination of these two approaches (see Focus, right). In both cases, data needs to be comprehensive enough (to allow monitoring of all forests in a country) as well as sensitive enough (to detect changes in forest cover according to the country's definition of forests).

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A COMBINED APPROACH TO MONITORING SYSTEMS

COURTESY OF NASA / USGS

There are two primary goals in developing forest monitoring systems. The first is to be able to measure and report information in a consistent and comparable manner to international conventions (see International policy context above). The second is as an early warning system, to notify regional and/or national authorities of likely immediate changes in forest cover. These two needs can lead to two different yet potentially complementary approaches to developing forest monitoring systems. The differences lie in the frequency of assessments and how data can be interpreted with regards to forest cover and dynamics.

Under a snapshot approach, two assessments of forest cover are carried out at different times (usually between reporting periods). A comparison of the results obtained is used to establish the changes in forests over this time period. With this approach, ground-truthing—by teams on the ground—is used, either for calibration of the methods or enhancement of the algorithms.

Using the phenology approach, remote-sensing data is collected continuously, allowing for instantaneous detection of any deviation from a normal trend. The type of change observed can be associated with partial deforestation (or degradation) as well as with the specific type of land-cover change that occurred.

A combination of these approaches can be developed, in which coarser resolution satellite imagery (e.g. MODIS) is used to identify areas where forest-cover changes may be occurring, and higher-resolution datasets (e.g. Landsat, RapidEye or GeoEye) can be used to characterize and verify these changes. (Field data may also be used when deemed necessary.) The data generated through these higher-resolution satellites can then also be included in periodic reports. Combining approaches allows for an optimization of logistical resources (including imagery acquisition and processing times) and provides multiple functionalities in forest monitoring systems.

Remote sensing technologies

Over the past decade, a range of free and paid-for satellite technologies have become available for forest monitoring. The choice of which remote sensing data to use is driven by just a few key factors.

Acquisition period: The timeframe for which data is available is critical. Satellite data is ideally acquired over a continuous period, both into the past, for the purpose of developing reference levels (based on historic deforestation and associated emissions) (see *Reference Levels* chapter), and into the future for on-going forest monitoring.

Acquisition frequency: Satellite data is typically not continuous; therefore the time period between image captures is a key factor in the choice of remote sensing technologies.

Spatial resolution: The spatial resolution of remote sensing systems ranges from sub-meter (e.g. Quickbird, Pleiades) up to sub-kilometre (e.g. MODIS). Common wisdom associates higher resolution with better quality of data as we get to "see the forest". However, this often comes with a trade-off in cost, processing times, required storage space, and in some cases acquisition frequency and spectral resolution (see below).

Spectral bands: Perhaps the most important consideration for remote sensing systems is the bandwidth or frequency of the image detection system. Different bandwidths allow for different land use and forest characteristics to be measured (e.g. biophysical parameters of vegetation such as chlorophyll content and humidity) and also offer other benefits (e.g. cloud penetration).

Table 1 lists the predominant remote sensing technologies currently available and their relevant characteristics.

The use of remote sensing technologies in recent years has shown that no single dataset will be able to deliver under all circumstances. Due to the great diversity of forest types and regional conditions and a lack of consistent coverage, formatting and processing needs (Sy et al., 2012), MMRV systems will need to use a combination of remote sensing technologies that establish synergies among available data sets and their characteristics.

Field data

Field plots are the second cornerstone of a forest monitoring system. Forest cover data generated via remote sensing sources needs field validation to enhance and calibrate the quality of the monitoring system, a process that is often referred to as ground-truthing. Deriving activity and/or forest cover change data and ground-truthing via field work are iterative processes allowing the constant enhancement of the monitoring system as well as that of the accuracy on the activity data.

Because the uncertainties in our field measurements will propagate through the entire MMRV system, the accuracy of our field measurements is one of the key components of the overall forest monitoring system. As field measurements are both costly and time consuming, however, selection of field sites through **stratification** and **sampling** is essential.

Stratification

Before any field measurements can be taken, forests need to be stratified into reasonably homogeneous types so that sample plots gathered from those areas are representative of the entire strata. These strata can be derived either from remote sensing data or from other ancillary data. The quality of the stratification will be a key determinant in how accurate are the carbon estimates generated for each forest type. Two-step stratification is usually recommended:

1. A preliminary stratification is carried out with sample field plots to assess how estimates behave statistically.

2. Based on initial estimates, ideal sample sizes (e.g. number of plots needed) and/or strata are generated.

It is common practice to base such stratification on a combination of factors, including forest type, soil type, topography, ecoregion, etc. In order to optimize logistical resources, it is advisable to incorporate additional factors into the stratification approach such as likelihood of deforestation of a given area. Because these areas are the most likely to produce emissions, higher accuracies are desired from these areas. When developing stratification strategies it will also be important to create approaches that can be easily translated across systems (i.e. between national forest inventories and UNFCCC reporting requirements).

Sampling

Once the stratification process is complete, we need to begin taking field measurements from samples within our strata. The number of samples will depend on the level of uncertainty needed for the MRV system, which in turn depends on how heterogeneous the individual strata are. Various tools are available that can be used for this process (e.g. Winrock Sampling Calculator *www.winrock.org/ecosystems/tools.asp*). If very large numbers of samples are required for a given stratum (because of large variance in forest areas), a reassessment of the stratification must be made as it is likely that new strata will need to be defined.

Pools

Field measurements typically follow a standardized approach. Because field measurements are the primary source of data to estimate forest carbon, certain key data needs to be gathered. The IPCC has identified five carbon pools that parties to UNFCCC are encouraged to report against:

- Above-ground biomass (AGB)
- Below-ground biomass (BGB)
- Deadwood
- Litter or dead organic matter (DOM)
- Soil organic matter (SOM)

During field measurements, practitioners will need to gather data across ideally all of these pools. Sometimes that is not possible, in which case only the most relevant pools will be assessed. Usually, the most significant pool in terms of carbon fluxes (changes in carbon) is AGB (i.e. tree biomass).[10] Direct measurement of AGB would mean felling trees and drying them to measure their biomass and thereby their carbon content. This is an expensive process, however, and is often neither possible nor desirable due to restrictions in our sample areas. Therefore, we often rely on estimates of AGB derived through **allometric equations** that are based on variables that have been shown to correlate with tree volume and hence biomass.

Community-based forest monitoring

Communities can play an integral role in forest monitoring systems (including measurement, reporting and verification). Studies have clearly established that data collected by communities on the ground is comparable to data collected by trained scientists (see, for example, Pratihast et al., 2013, Danielsen et al., 2011). Examples of tools that can help incorporate communities in forest monitoring activities include the Geo-Wiki project with its biomass branch (*biomass.geo-wiki.org/login.php?ReturnUrl=/index.php*; Fritz et al., 2009) and Google's Open Data Kit (see, for example, MOABI *drc.moabi.org*).

WEBINAR VIDEO: SATELLITE DATA FOR REDD+ MRV

LEARNING SESSION 7

SNAPSHOT CASE STUDY

PARTICIPATIVE DEVELOPMENT OF A BASELINE FOREST CARBON MAP IN THE PERUVIAN AMAZON

For more information, read the full Inspiring Practice at bit.ly/10MktlI

Context
The Regional Government of Madre de Dios (GOREMAD) needed to implement a land use plan for its natural resources that both fulfilled a national mandate from the Ministry of Environment and followed the REDD+ nested approach adopted by Peru. To do this, GOREMAD sought to collect data on deforested areas. Although information from various isolated studies was available, none of it was officially validated. There was also a growing demand for official information on deforestation, as many REDD+ initiatives started up in the region. In 2009, GOREMAD created the Roundtable of Environmental Services and REDD+ (MSAR), whose work focused on land-use planning, sustainable development, and tools and mechanisms for climate change mitigation.

Expected changes
The work in Madre de Dios of WWF's Forest and Climate Initiative focused on developing an affordable, technically feasible and effective regional participatory monitoring system designed and tested in coordination with the national and regional governments.

Achievements
Building local MMRV capacity. In 2011, WWF and Universidad Nacional Amazónica de Madre de Dios (UNAMAD) developed the first Diploma of Environmental Management and REDD+ with specialization in MMRV. After five months of rigorous training, 35 participants from GOREMAD, NGOs and universities—along with private professionals—graduated with a newfound understanding of the complex topic of MMRV.

Definition of processes and methodologies to complete the deforestation baseline. Experts and officials worked to define the methodology to estimate the deforestation baseline in accordance with international guidelines and standards. The process involved comparison of methods and tools that were proposed by a large number of national and international organizations. The National Agrarian University of Lima developed the selected methodology and also provided technical support to complete the map using data up to 2010. MSAR recognized this process and submitted it to GOREMAD so that it would be defined as a technical standard.

Analysis and recommendations for the development of a biomass and carbon map. The Biomass and Carbon Baseline subcommittee for Madre de Dios, led by WWF, compiled information from 600 forest quadrants installed by various public and private organizations. The University of Leeds (United Kingdom) analyzed the data coming from those quadrants, identified the gaps and suggested a protocol to measure forest carbon in Madre de Dios.

Challenges

- Management discontinuity and political instability led to frequent changes in GOREMAD authorities, prevented smooth progress and impacted planned programmes.
- Participatory processes often take longer than anticipated. Although the strength of this initiative came from the fact that local groups and the regional government worked together, this took significant time.

Lessons learned

- **MMRV tools need to be flexible, simple to use, easily available and appropriate for the context.** Technical tools should be developed taking the local situation, local technicians and local capacities into consideration. Using tools that don't meet the specific needs of the community hinders work.
- **It is necessary to define agreed-upon criteria to select the correct methodologies for the region.** In Madre de Dios there were six studies on deforestation that encouraged comparisons and discussions on the most adequate approach for REDD+ projects.

SNAPSHOT CASE STUDY

BRAZIL'S FOREST MONITORING SYSTEM

Brazil has developed its own MMRV system based on the experience and expertise of INPE. The system is composed of five subsystems:

1. DETER (www.obt.inpe.br/deter) uses high temporal and spectral resolution data from MODIS to establish "normal" phenologic trends for forest cover. Any deviation to this trend allows for the identification of priority areas for further assessment. Brazil uses DETER as a first cut into tracking deforestation and degradation.

2. PRODES (www.obt.inpe.br/prodes) has been used as the official approach to deforestation tracking since 1988. It is based on high spatial resolution data (Landsat-type data; 30m spatial resolution, acquired every two weeks, 5–7 bands).

3. DEGRAD (www.obt.inpe.br/degrad) is used for degradation tracking and combines the results of the DETER and the PRODES systems in order to assess degradation trends. The combination of the high radiometric and temporal resolution of the DETER products with the high spatial resolution of the PRODES outputs allows for a first-cut assessment of forest degradation trends.

4. Terra Class (www.inpe.br/cra/projetos_pesquisas/terraclass.php) for land-use characterization (a.k.a. activity data) is basically the land cover mapping project that Brazil has for the Amazon.

5. INPE EM (inpe-em.ccst.inpe.br) is a system that translates all these datasets into emissions estimates.

Forest fires are also monitored as a proxy to early stages of deforestation via the thermal anomaly product of the MODIS sensor.

Measurement (M_2)

The purpose of the measurement (M_2) system is to convert information from our forest monitoring systems into the emissions reductions and removals that result. The IPCC GPG for LULUCF defines measurement systems as the continuous collection of data on anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes (Forestry and Forest Products Research Institute, 2013).

Deriving carbon estimates in plots

The first step in converting forest monitoring data into reportable measurements expressed in tCO_2e is to use allometric equations to estimate the carbon content in individual trees. Allometric equations can either be a set of predefined equations based on general species types and forest compositions, or they can be specifically tailored to a particular forest area developed using, for example, local measurements and even destructive sampling of forest areas. This latter approach, however, is both costly and environmentally degrading as it requires the destruction of a representative number of trees for a given forest type.[11] In any case, the difficulties involved in carrying destructive sampling and developing new specific allometric equations mean that predefined equations are often used to estimate forest carbon stocks.

The IPCC has established a system of *three tier levels for the estimation of biomass:* Tier 1 uses generic equations and data; Tier 2 uses generic equations but uses data acquired at a national level by means of a national forest inventory; and Tier 3 uses both nationally produced allometric equations and national field data. It is assumed that as tier levels increase, the accuracy of our estimates also increases.

From plots to a carbon map

The second stage in measuring for REDD+ is to scale up our plot estimates of forest carbon to the jurisdictional or national level using remote sensing and ancillary data. The most common and simple approach is to average plot data across each of the forest strata[12] to estimate the forest carbon content, including error estimates. This redoubles the importance of accurately mapped forest strata because poorly defined strata will lead to large variance in forest carbon estimates and therefore to large confidence intervals.

When plot data is not sufficient, relationships between plot data and other independently collected variables (e.g. tree height, canopy density, elevation) may be used. These variables are often derived from remote sensing data or other ancillary data (e.g. topography and elevation maps). Examples of such synergies between plot data and other datasets currently being explored include the use of high spatial resolution remotely sensed data from which canopy height (e.g. LiDAR) or canopy crown sizes (e.g. Ikonos, Quickbird, GeoEye) can be estimated.[13] These datasets, however, can also be technologically demanding and expensive to obtain when thinking in terms of the total coverage of large countries and considering that synergies are still being characterized. Error propagation of carbon estimates from the plots to the final outputs is of special concern because it is poorly understood how this happens.

TABLE 1: LIST OF AVAILABLE SATELLITE DATA, SOURCES AND APPLICATIONS

NAME	SOURCE	AVAILABLITY DATE	RESOLUTION	FREQUENCY	SPECTRAL BANDS	USES	SOURCE
LOW RESOLUTION							
MODIS	NASA	1999–	250m-1km, ~10degree tiles	Twice daily	36 bands, for land, water, atmosphere	Fire detection, real-time monitoring, daily snapshots, phenology, regional studies, long-term trends, vegetation indices	» Info on MODIS Data: modis.gsfc.nasa.gov/data » Search and download raw and derived data products from Reverb (registration required): reverb.echo.nasa.gov » Or GLCF for derived products: glcf.umiacs.umd.edu/data/modis
SeaWifS	NASA	1999–	9km	Daily	8 bands	Water quality, chlorophyll, sediment	Data download from Oceancolor web (registration required): oceancolor.gsfc.nasa.gov/
SPOT-VGT	VITO	2002–2012	1km	Daily	Red, blue, NIR, SWIR, composite vegetation index	Surface mapping, basic vegetation and canopy	» Read documentation for how to convert DN » Background information: www.vgt.vito.be/index.html » Free products: free.vgt.vito.be
MERIS/ ENVISAT	ESA	2002–2012	300m, swath width 1150km	3 days	15 bands	Land and water mapping	Data access through ESA application, multiple web clients: https://earth.esa.int/web/guest/data-access/catalogue-access
MEDIUM RESOLUTION							
ALOS PALSAR	JAXA	2007–2010	25m, 50m resolution	Annual mosaics	HH, HV polarization	Forest mapping, biomass, change detection, cloudy areas	» Processed mosaics for Africa and SE Asia available in GTIFF from WWF Germany. » HDF 50m mosaics can be download from the K&C website: www.eorc.jaxa.jp/ALOS/en/kc_mosaic/kc_map_50.htm » Additional requests for 25m data can be made through K&C
ALOS AVNIR	ALOS AVNIR	2007–2010	10m, 70km swath	2 days	Blue, green, red, NIR	Land cover mapping and quick disaster response	» Search archive and order through Pegasus: en.alos-pasco.com/sample/pegasus.html
ASTER	NASA	1999–	15m/30m/ 90m, 60km x 60km tile	Weekly	15 bands: 4 visible and NIR, 6 short-wave IR, 5 thermal bands (90m), 1 stereo	Land- cover mapping, change detection, real-time monitoring	» Data can be browsed and downloaded from Earth Explorer: earthexplorer.usgs.gov or Glovis: glovis.usgs.gov » List of ASTER Derived products: https://lpdaac.usgs.gov/products/aster_products_table
AWIFS	Indian Space Research Organization	2003–	56m, 370 x 370km	5 days	4 spectral bands: green, red, NIR, mid-IR	Land cover mapping, change detection, crop yields, large-scale analyses	Data can be searched through the National Remote Sensing Centre of India: 218.248.0.130/internet/servlet/LoginServlet or through a reseller; data can be freely available for Amazon (Resource-Sat www.dgi.inpe.br/CDSR)
Corona	USGS	1960–1972	10m, 22km x 22km	Intermittent	Panchromatic camera	Historical mapping	Searchable via selecting Declassified Data in Earth Explorer: earthexplorer.usgs.gov
ICESat/GLAS	NASA	2003–2010	60m granules/ footprints	891 days	LiDAR: Altimetry, back-scatter	Forest canopy height, elevation, sea ice thickness	Coverage is not continuous; data must be filtered for quality: nsidc.org/data/icesat
KOMPSAT	Korea Aerospace Research Institute	2006–	1m panchro-matic, 4m multispectral, 15km swath	14 days	Blue, green, red, NIR	Disaster surveillance, vegetation and coastal monitoring	» www.kari.re.kr/data/eng/contents/Space_001.asp?catcode=1010111000&depthno=0 » Imagery donations for climate change projects: www.planet-action.org
Landsat	USGS	1982–2012	30m, 185km x 185km	14 days	Red, green, blue, NIR, mid-IR, thermal IR (60m); Landsat 7 includes a pan-chromatic (15m) band	Land cover mapping, vegetation studies, change detection, long-term studies, marine mapping	» Landsat 7 ETM+ data collected after May 2003 has striping issues. Landsat 5 TM is still collecting, though not everywhere. » Data can be browsed and downloaded from Earth Explorer: earthexplorer.usgs.gov or Glovis: glovis.usgs.gov

Extrapolating plot data by means of these independent variables has allowed the creation of global carbon estimates maps as well as carbon estimates error maps (for examples, see Saatchi et al., 2011, Harris et al., 2012).

Reporting (R)

Reporting requirements for REDD+ will differ depending on whether REDD+ is being implemented at the national level under the UNFCCC or at the project level. In this section, only the reporting requirements for implementation at the national level are discussed. Reporting is defined under the IPCC GPG for LULUCF as "the process of providing estimates to the UNFCCC". The UNFCCC has given clear guidance on reporting systems for developing countries. Under their BURs (see Focus on Reporting systems for REDD+ in DRC), developing countries are required to submit detailed accounts every two years that show the changes in forest carbon stocks. These reports must be written in line with the latest LULUCF guidelines and expressed in tonnes of carbon dioxide equivalent (tCO_2e). IPCC GPG further recommends that reporting systems should be comprehensive and that all information related to emissions reporting should be readily accessible and available for assessment. Reporting systems should also be complete and transparent, with explanation of remote sensing and field data and the methods used to allow others to fully reproduce the results of the measurement and reporting systems.

Given that this will be a very data-intense system, many countries will need to expand their technical capacity to report on forest carbon measurements (bearing in mind that they will be able to progress in a stepwise approach through the various tiers). Countries will also need to develop online interfaces to manage this data. There are already several examples of such systems being developed by various organizations (see Focus on Reporting systems for REDD+ in DRC). These systems will certainly need to include information on carbon stock changes but, depending on the level of advancement in reporting systems, they may also need to include geospatial data on land cover change. Ground survey requirements for these types of tool, however, are extremely high and may only be practical over relatively small, homogeneous, or well-known areas.

Reporting errors

Error reporting will be an essential component of our measurement and reporting system. Because errors propagate through the system, a **parsimony approach** (i.e. the least number of steps) can be used to avoid increasing the sources of errors during carbon estimation. The fewer variables and intermediate datasets that are used to obtain estimates the fewer measurement and correlation errors there will be in overall estimates; the parsimony approach will also help to make the process more transparent and adaptable (as simpler systems are easier to assess and verify).

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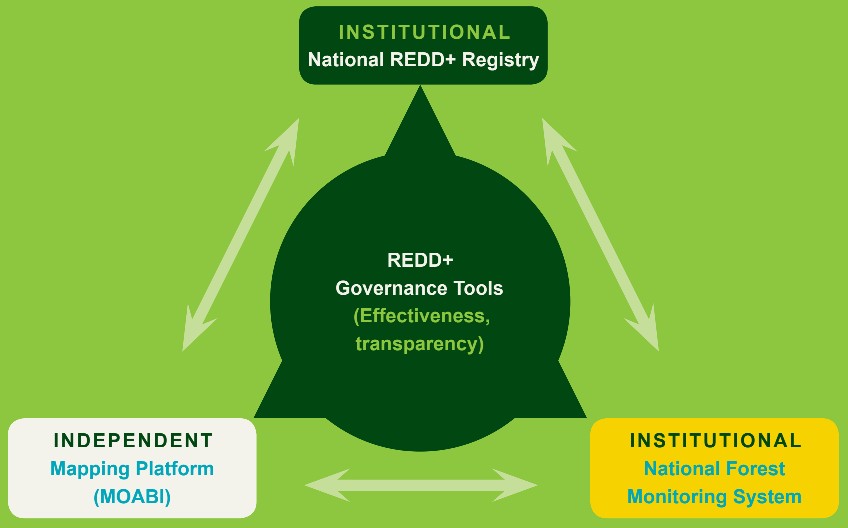
REPORTING SYSTEMS FOR REDD+ IN DRC

The Democratic Republic of Congo (DRC) is developing a three-tiered reporting system for REDD+.

The first component is the National Forest Monitoring System (Système National de Suivi du Couver Forestier) (www.rdc-snsf.org), currently being developed with the support of UN-REDD and the Instituto Nacional de Pesquisas Espaciais (INPE) from Brazil. This system will seek to integrate data on forest cover collected at different scales, from the community level to the subnational and national levels. The reporting system will compile, integrate and analyze a wide spectrum of data based on the use and interpretation of remote sensing data and emissions factors issued from field inventory data and other sources.

The second institutionally managed tool is the National REDD+ Registry, which aims to collect, gather and share data on REDD implementation activities. For more information, see the REDD+ Registries chapter.

The third component is a collaborative Independent Mapping Platform called MOABI (rdc.moabi.org). This system allows the community to track and report development-related events such as large-scale projects, as well as deforestation events, and to also report validation data for government-generated information. This tool can be used for validation/verification of reported data, crowd sourced feedback, as well as assessment and update of drivers of deforestation.



Verification (V)

The final component of the MMRV system is verification. Verification is an essential step in ensuring that (often self-reported) data is consistent with and meets the requirements laid out by international (or other third-party) standards. Under the IPCC GPG for LULUCF, verification is referred to as "the collection of activities and procedures that can be followed during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of that inventory". There are several options for how changes in forest can be verified, and again this section will focus on national-level processes (with subnational-level verification as an interim measure) under a future REDD+ mechanism.

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Under the UNFCCC it was agreed that developing countries should verify their emissions reductions using a process called International Consultation and Analysis (ICA). The ICA process will consist of two steps:

- A technical analysis of biennial update reports (BURs) by a team of technical experts in consultation with the UNFCCC party, resulting in a summary report. The information considered should include the national GHG inventory report along with NAMAs, including their impacts and the progress made in their implementation.
- A facilitative sharing of views, which will have as input the BURs and summary report referred to above.

The level of rigor for the verification system will depend greatly on the end use of the emissions reductions. If measured and reported emissions reductions are intended to be used for compliance purposes or as offsets, then strict standards will need to be applied to verification in line with national GHG inventory reporting under the UNFCCC or CDM.

Under the UNFCCC, verification is done through quality control and quality assurance mechanisms, either by those directly involved in the calculation or by a third party (Forestry and Forest Products Research Institute, 2013). On the other hand, within carbon markets, verification is done ex-post by an independent third party to confirm that the monitoring and reporting has been conducted according to prescribed methodologies.

Although guidance exists, many countries are still only in the early stages of development of their verification systems. In Doha there was also significant pushback by forest-owning countries against independent verification.

Early examples of independent verification systems have also emerged (e.g. MOABI in DRC) that use a combination of crowdsourcing and third-party data collection to verify forest area change.

WWF VIEWPOINT

WWF has developed several positions on MMRV for REDD+. In the run-up to Doha in November 2012, WWF produced a position paper on MMRV that called for REDD+ MMRV systems that are robust and accurate and that are consistent, comparable and generated in a transparent manner. This position paper is available at: *bit.ly/143srBA*.

Prior to that, WWF developed recommendations for the UNFCCC SBSTA meeting in June 2012 that called for efficient, inclusive and accurate MMRV systems. In these recommendations, WWF also stated that forest degradation and biodiversity should initially be tracked using proxy indicators. These are available at: *bit.ly/15GMC8y*.

FURTHER RESOURCES

GOFC-GOLD REDD+ Sourcebook, available at: *www.gofcgold.wur.nl/redd*

GOFC-GOLD Fire Project, available at: *gofc-fire.umd.edu*

IPCC Good Practice Guidance for Land Use, Land-use change and Forestry, available at: *www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html*

IPCC Guidelines for National Greenhouse Gas Inventories, available at: *www.ipcc-nggip.iges.or.jp/public/2006gl*

MRV Community of Practice—REDD+ Community, available at: *www.reddcommunity.org/mrv-community*

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END NOTES

1. Decision 2/CP.13.
2. ibid. Noting that the decision only requires reporting on deforestation.
3. Including, if appropriate, subnational systems as part of national monitoring systems and recognizing again the IPCC GPG for LULUCF.
4. Decision 4/CP.15.
5. Decision 1/CP.16.
6. FCCC/SBSTA/2012/L.9/Rev.1.
7. “Complete” means the provision of data and information that allows the technical analysis of the results.
8. Described in Annex III to Decision 2/CP.17.
9. Described in Annex IV of Decision 2/CP.17.
10. This is not always the case. For instance, in peat swamps BGB is the dominant source of carbon fluxes.
11. This type of data can be gathered from forest management concessions; however, this approach limits the scope to commercial species only.
12. Identified in the stratification process.
13. Synergies among plot data and ancillary data are currently being explored. The feasibility of using such synergies has been established (Asner et al., 2009, 2010, 2011, Skole et al., 2009).