

Monitoring and measuring changes in above-ground biomass in tropical forests

National schemes for monitoring tropical forests and their associated carbon stocks will be critical to reducing emissions from deforestation and degradation within the post-2012 climate regime. Operational forest monitoring is now a feasible goal for most developing countries, although significant barriers to the widespread implementation of national monitoring programmes remain. This background note describes the components of schemes to monitor carbon in above-ground forest biomass, and outlines key steps that need to be taken to by national governments and international efforts to ensure the effectiveness of forest monitoring.

National forest monitoring: essential to participate in REDD

The post-2012 international climate regime is likely to include a 'REDD+' outcome* for countries that were not listed under Annex 1 of the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC). To participate in REDD+, nations will need to have a reproducible, consistent and transparent means of estimating changes in forest carbon stocks, in line with Intergovernmental Panel on Climate Change (IPCC) guidelines. The nature of the monitoring system will need to be tailored to individual countries' technical requirements and national REDD+ strategy. It is important for countries to use consistent methods through time to enable comparison of forest carbon stocks between time intervals ⁽¹⁾.

Since the idea of reducing forest emissions was first put forward by Papua New Guinea and Costa Rica at the 2005 Montreal Conference of the Parties to the UNFCCC, expert groups have been working to define how forest carbon monitoring schemes could be constructed ⁽¹⁻⁷⁾. An ad-hoc REDD working group, the Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD), compiles a working sourcebook that details how to set up forest monitoring programmes ⁽⁸⁾. Operational forest monitoring for REDD+ is now seen as a feasible goal for most non-Annex 1 countries ⁽⁷⁾.

The mechanics of measuring changes in forest area and carbon stored in above-ground biomass

The scientific base for national schemes to measure and monitor deforestation is now well-established, whereas measuring degradation is technically more challenging ⁽⁹⁾. Estimating emissions from deforestation requires assessment of the area of cleared forest, and of the change in carbon stored in the cleared area ⁽²⁾. Forest carbon can be stored within the soil, within vegetation as above-ground and below-ground biomass, and within litter and dead wood. In tropical forests, above-ground biomass (AGB) is usually the most significant component of the total carbon stock, and the easiest component to measure. Although this note details only procedures for measuring change in AGB, change in other carbon pools may be significant in some forest types. For example, changes in soil carbon stocks may be very important in areas with carbon-rich peat soils.

The first step in all forest monitoring programmes is to compile a map of existing forest cover, based on national definitions that fit within IPCC guidelines ^(see 9, 10). Updates of the forest cover map will be needed to determine changes in forest area within pre-determined time intervals. At the national level, this will likely require the use of remotely sensed data ⁽³⁾ (which includes both aerial photography and information gathered from plane- and satellite-mounted sensors), and could also incorporate data gathered from national forest inventories (NFI). Countries must use field data to verify that maps produced using remote sensing data relate to actual changes in forest area. Persistent cloud cover in some regions presents a challenge to mapping based solely on photography and optical data.

Countries will need to compare the rate of forest loss against an agreed 'baseline' or 'reference level'. Based on the availability of historical data on land cover change (including archived images from medium-resolution optical satellite-mounted sensors such as 'Landsat' ⁽¹¹⁾), it makes sense to develop historic emission levels from the mid 1990s to 2000 onwards. While methods and procedures are available for developing estimates of historic forest emission levels, there is still considerable negotiation around how to use this information to project future emissions under a 'reference' scenario ⁽¹²⁾ (i.e., business-as-usual without REDD+).

Countries will need to estimate how much carbon was contained within the area of cleared forest, using at least one of several established procedures. Examples of such procedures include assigning an average carbon value to mapped forest types, or using ground-based measurements of tree characteristics (such as diameter, height and wood density) to assign carbon values for forests using predictive relationships. Although not ready for widespread adoption, new technologies are emerging that use remote sensing data from synthetic aperture radar (SAR) and light detection and ranging (LIDAR) sensors to estimate AGB. LIDAR shows promise in measuring the three-dimensional structure of forest in cloud-free areas, whereas SAR can penetrate clouds and detect change in forest cover ⁽¹³⁾. A well-managed observation portfolio integrating data from different systems (i.e., NFIs, other field data and remotely sensed data) can reduce forest monitoring costs ⁽¹⁴⁾.

* 'REDD+' refers to: reducing emissions from deforestation and degradation; increasing removals from enhancement of forest carbon stocks; forest conservation; and sustainable management of forests.

Degradation includes anthropogenic processes that decrease forest carbon, such as selective logging, fire, wood and plant collection, and livestock browsing⁽⁸⁾. To quantify forest degradation, countries will need to map the area of degraded forest and estimate the proportion of total forest carbon lost from within these areas⁽⁵⁾. Forest degradation is more difficult to monitor with remote sensing data than deforestation, owing to the complex mosaic of land cover types, and to the rapid change in forest characteristics (such as canopy damage and regrowth after fire)⁽⁸⁾. As a result, very high resolution images and/or intensive field mapping is required, as well as frequent updates, increasing the costs associated with monitoring^(15, 8). Methods have been developed to detect degradation due to selective logging in some situations using remote sensing data⁽¹⁵⁾. Remote detection of changes to forest canopy through fuelwood collection may not be possible with current technology⁽⁸⁾, and will almost certainly require ground-truthing and field mapping of degradation 'hot-spots'.

Current status of national forest monitoring programmes

A number of countries are moving forward with 'wall-to-wall', or national, forest monitoring programmes. The Brazilian National Space Agency (INPE) has a comprehensive annual monitoring programme⁽¹⁶⁾ that has undertaken annual assessments of deforestation in the legal Amazon since 1988 using Landsat and other imagery, including assessment of deforestation 'hotspots'⁽⁸⁾. A newer initiative, 'DETER', provides near real-time updates on recent deforestation events larger than 25 ha based on MODIS imagery⁽¹⁷⁾, which has been available since 2000. INPE is also working on a new system to monitor forest degradation⁽⁸⁾. The Forest Survey of India has undertaken national forest assessments on a two-year cycle since the early 1980s, which includes six months of ground-based measurements and verification^(18, 8). Cameroon has initiated a REDD pilot project as a prototype case for the Central African Forest Commission, which includes wall-to-wall forest mapping and regional estimates of degradation⁽¹⁹⁾. Country-wide analyses of changes in forest cover have also been undertaken in the Democratic Republic of Congo⁽²⁰⁾. A recent assessment indicated wide variation in country capacity for monitoring forest area change and compiling forest inventories⁽²¹⁾.

Several partnerships have been forged to develop forest carbon monitoring programmes. Australia is using experience from its National Carbon Accounting System (NCAS) to provide technical advice to Indonesia and Papua New Guinea to aid in the design and development of systems that are appropriate to their national circumstances. Similarly, Canada is working with the Mexican Ministry of Forests to ascertain whether the Canadian forest sector's carbon budget model can be applied in Mexico⁽⁸⁾. The Clinton Climate Initiative has convened the Carbon Measurement Collective to build a prototype system based on Australia's NCAS, which is proposed to be tested in Guyana. The World Bank's Forest Carbon Partnership Facility and the UN-REDD programme both support national activities related to forest carbon monitoring and reporting.

Key steps to promote effective forest monitoring for REDD+

Many of the key constraints to setting up effective forest monitoring for REDD+ participation can be overcome with funding and technology exchange from developed countries. Forest monitoring programmes will require trained staff, funding and capacity for field-based ground-truthing, access to appropriate data (including remote sensing data, existing land cover change products and technical information), software, hardware, broadband internet connection and an institutional body responsible for coordinating and reporting on forest monitoring.

The costs to set up and run monitoring programmes will vary greatly between countries, depending on the level of existing technical and institutional capacity and the area of forest⁽²²⁾. Costs will also vary with the level of accuracy and precision required for estimating carbon emissions and removals, the length of time between monitoring events, and the spatial resolution required for any remote sensing data. Some of required data is costly, although a large amount is free, including Landsat and MODIS products. Space agencies and data providers are working on bridging the gap between acquiring satellite data and their availability for use, and on pre-processing remotely sensed data into a format suitable for use by national forest carbon monitoring programmes⁽²³⁾.

Forest carbon monitoring programmes will need to be tailored to individual country circumstances, whilst conforming to the requirements of existing IPCC guidelines for national carbon estimation^(9, 10) and emerging needs for REDD+. Agreement on national definitions of forest cover, land cover classifications, deforestation and forest degradation that fit within the IPCC guidelines will be an essential part of the monitoring and reporting system. National programmes will need to consider characteristics that are specific to different regions, such as steep topography, persistent cloud cover, seasonality, labour costs, availability of existing data and country size⁽²¹⁾. National programmes will also need to define the most appropriate balance of ground-based inventories, statistical models, aerial photography and other remotely sensed data to detect changes in forest carbon stocks. Technological advances in remote sensing, data analysis, detection of forest degradation, and on the relationships among forest type, biomass and carbon stocks will improve the accuracy and certainty of forest carbon monitoring.

Over time, forest carbon monitoring programmes may need to fit in with wider terrestrial carbon estimation and reporting systems for agriculture, forestry and other land uses (AFOLU)⁽¹⁰⁾. Funding, research and development will be needed to assist countries to report on terrestrial carbon at the highest possible level if AFOLU guidelines are approved in the future.

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