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Global Observation of Forest and Land Cover Dynamics
Land Cover Project Office

An assessment of national forest monitoring capabilities in tropical non-Annex I countries:

Recommendations for capacity building

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for

The Prince's Rainforests Project and
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Executive Summary

The objective of this study was to specify and scope, for 99 tropical non-Annex I countries, the near-term capacity-development activities that would be required to implement an accurate forest area change and carbon stock monitoring system. The focus is on actions that could be taken over the next five years to prepare for participation in a mechanism for Reducing Emissions from Deforestation and Forest Degradation (REDD), or in an intermediate funding mechanism, such as the one currently being debated in the International Working Group - Interim Financing for REDD (IWG-IFR). This Working Group was an outcome of a meeting of world leaders, hosted by His Royal Highness, the Prince of Wales, held in London on April 1st 2009. Furthermore, the report may provide useful input to REDD-readiness processes, such as those undertaken in the framework of the UN-REDD Programme and the Forest Carbon Partnership Facility (FCPF).

Information from various consistent global information sources was analyzed to assess current national capabilities and – based on the results – make recommendations for capacity development for each country. The study used two types of information sources. International reporting and communications to the United Nations Food and Agriculture Organization (FAO), to the United Nations Framework Convention on Climate Change (UNFCCC) and to the World Bank have been reviewed and analyzed along with information from global data products reflecting relevant factors such as availability of data and observations, forest status and threats, current carbon stocks and technical challenges for implementing annual forest area change monitoring. Although the study considers various aspects of a national forest carbon monitoring system, there is an emphasis on capacities for the monitoring of forest area change and the role of remote sensing technologies.

The assessment of current monitoring capabilities has emphasized that the majority of countries have limitations in their ability to provide a complete and accurate estimation of greenhouse gas (GHG) emissions and forest loss. Less than 20% of the countries have submitted a complete GHG inventory so far, and only 3 out of the 99 countries currently have capacities considered to be very good for both forest area change monitoring and for forest inventories. The major shortcomings in the current monitoring capacities can be summarized according to the relevant reporting principles of the Intergovernmental Panel on Climate Change (IPCC) in their Good Practice Guidelines (GPG):

- **Consistency:** Estimations previously provided by many countries are based either on single-date measurement or on integrating heterogeneous data sources, rather than using a systematic and consistent measurement and monitoring approach;
- **Transparency:** Expert opinions, independent assessments or model estimations are commonly used as information sources to produce forest carbon data; this could potentially lead to a lack of transparency;
- **Comparability:** Common methodologies and guidance must be used to produce comparable results. Few countries have experience in using the IPCC GPG as a common approach to estimation and monitoring;
- **Completeness:** The lack of suitable data for measuring and monitoring forest area change and changes in carbon stocks in many non-Annex 1 countries is evident. Carbon stock data for above ground and below ground carbon are often based on estimations or conversions using IPCC default data and very few countries are able to provide information on all five carbon pools or estimates from biomass burning.
- **Accuracy:** There is limited information on sources of error and uncertainty levels of the estimates provided by countries, and approaches to analyze, reduce, and deal with these in international reporting

The capacity gap can be defined as the difference between what is required and what currently exists for countries to measure and verify the success of REDD implementation actions using the IPCC GPG.

As a synthesis of this study, the figure below indicates the current distribution where the largest capacity gaps exist for countries:

- that have limited experience in estimation and reporting of national GHG inventories, in application of the IPCC GPG, and with limited engagement in the UNFCCC REDD process so far;
- with low existing capabilities to continuously measure forest area changes and changes in forest carbon stocks as part of a national forest monitoring system; reporting carbon stock changes on the IPCC Tier 2 level is considered a minimum requirement;
- that face particular challenges for REDD implementation that may not be relevant for all countries, (e.g. they have high current deforestation rates and significant emissions from forest degradation, biomass burning and soil carbon stocks are currently not measured on a regular basis) and require investments to observe more IPCC key categories and move towards Tier 3 level measurements;
- where the availability of useful data sources for REDD monitoring is constrained. In this study the focus is on the availability of common satellite data sources (i.e. Landsat, SPOT, CBERS) that may be limited in their use due to lack of receiving stations, persistent cloud cover, seasonality issues, topography or inadequate data access infrastructure.

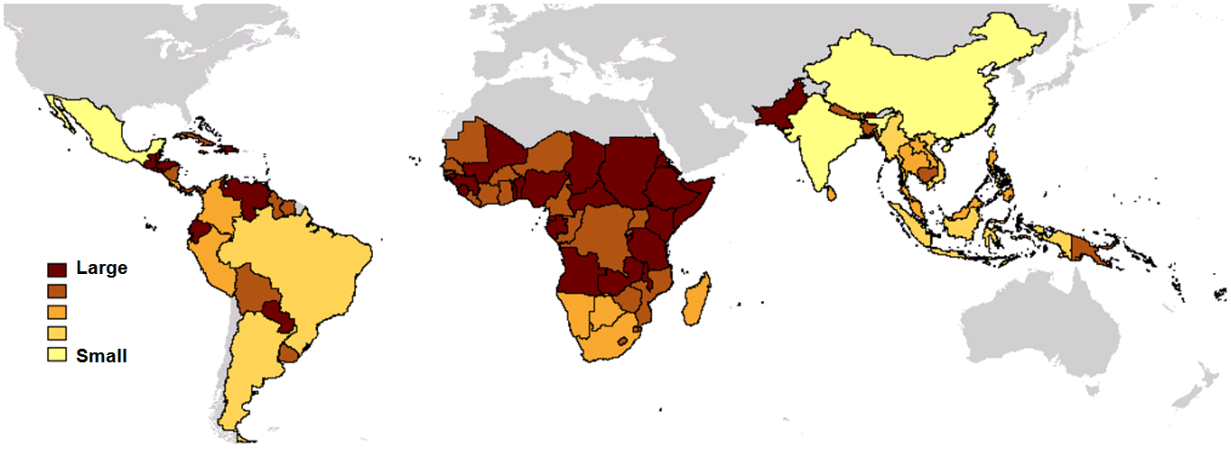

Figure: Spatial distribution of the capacity gap for different countries analyzed.

For each country, various indicators have been derived that help to assess their existing capabilities and to specify the next steps for developing a monitoring system. Recommendations are made for planning and designing a national REDD monitoring system including: organizational and institutional frameworks, assessing current capacities and existing data sources and information; steps for establishing a national monitoring system including components for consistent, multi-date forest area change monitoring (activity data), measurement and estimation of carbon emissions from land use change and remaining forest areas, consideration of emissions from other carbon pools and biomass burning, accuracy assessment and verification; and for national estimations and international reporting. Generic recommendations are provided for all 99 countries and more detailed suggestions are made for a selection of 30 countries in detailed country reports. It is concluded that almost all the countries studied require further investments to bridge the capacity gap in developing and sustaining national carbon measurement and monitoring systems in the long-term.

In addition to the country recommendations, the study highlighted some recommendations for international efforts and activities that would help to quickly and significantly remove some of the current obstacles for implementing annual forest monitoring; particularly:

- Improve the satellite data coverage through investing in additional receiving stations in particular in Central Africa and Central America.

- Provide resources and support ongoing activities for coordinated global forest observations through established international mechanisms.
- Implement regionally-specific, coordinated observation strategies to overcome specific challenges such as persistent cloud cover, data access limitations and lack of pre-processed data for annual coverage.
- Ensure that suitably pre-processed observation products are made available to all countries.
- Engage with relevant countries and actors to ensure long-term continuity of satellite observations for key observation programs with global focus, i.e. from NASA (National Aeronautics and Space Administration) and USGS (United States Geological Survey), ESA (European Space Agency) and EC (European Commission), JAXA (Japan Aerospace Exploration Agency) and INPE (National Institute for Space Research).

The results of the study also encourage regional cooperation to ensure efficient use of resources (National Institute for Space Research in particular for remote sensing capacity building) and to foster South-South cooperation. A number of international organizations are already working on forest monitoring issues in different parts of the tropics e.g. FAO Forest Resource Assessment and National Forest Monitoring Assessment Report, Global Observations of Forest and Land Cover Dynamics (GOFC-GOLD) and their regional networks. There is also great potential for some of the non-Annex I countries with suitable existing capacities and long experience of conducting forest inventory and monitoring to engage in regional cooperation and South-South capacity development (e.g. India, Brazil, Mexico). Some promising areas where, for example, regional cooperation would be a suitable option are in different regions of Africa (i.e. Central Africa), Latin America, South Pacific, Mekong river countries and other Asian and SE-Asian countries.

The study emphasizes the diversity of existing forest monitoring capabilities and the important near-term objective for any REDD readiness activities. Based on the understanding of monitoring requirements, existing capacities and avenues to further develop and establish operational capabilities, the study results point to the urgent need and opportunity to take immediate action. Capacity building activities should consider the different entry points for countries in this process and work towards an ultimate goal that all interested countries have a minimum level of monitoring capacity in place within the next five years.

Table of Content

Acronyms

AFOLU	Agriculture, forestry and other land uses
ALOS	Advanced Land Observing Satellite (owned by JAXA)
Annex 1 Countries	Signatories to the UNFCCC are split into three groups: Annex I countries (industrialized countries), Annex II countries (developed countries which pay for costs of developing countries), Developing countries
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer (NASA)
CB	Capacity building
CBERS	China-Brazil Earth Resources Satellite Program
CEOS	Committee on Earth Observation Satellites
COMIFAC	The Central African Forest Commission
DMC	Disaster Monitoring Constellation (survey satellites)
EC	European Commission
ESA	European Space Agency
FAO	United Nations Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility of the World Bank
FRA	Forest Resource Assessment
GEO	Group of Earth Observation
GHG	Greenhouse gas
GLCN	Global Land Cover Network (GOFC-GOLD)
GOFC-GOLD	Global Observations of Forest and Land Cover Dynamics
GPG	Good Practice Guidance
INPE	National Institute for Space Research (Brazil)
IPCC	Intergovernmental Panel on Climate Change
IRS	Indian Remote Sensing Satellite
JAXA	Japan Aerospace Exploration Agency
LC	Land Cover
LULUCF	Land Use, Land Use Change and Forestry
MERIS	Medium Resolution Imaging Spectrometer (NASA)
MODIS	Moderate-resolution Imaging Spectroradiometer (NASA)
NASA	National Aeronautics and Space Administration
NFMA	National Forest Monitoring Assessment Report of FAO
PRP	The Prince’s Rainforests Project
REDD	Reducing Emissions from Deforestation and Forest Degradation
R-PIN	Readiness Project Idea Note (submitted by countries to FCPF)
RS	Remote Sensing
SPOT	Satellite Pour l'Observation de la Terre (France)
SRTM	Shuttle Radar Topography Mission
USGS	United States Geological Survey
UNFCCC	United Nations Framework Convention on Climate Change
VCF	Vegetation Continuous Fields

1 Background and objective

The study has been conducted by the GOFC-GOLD Land Cover Project Office at The Friedrich-Schiller University of Jena, with the objective of summarizing the current capabilities of tropical, non-Annex I countries to monitor their forest resources with respect to forest area change and associated carbon stock changes and making recommendations for the implementation of operational forest monitoring within 5 years. The analysis was done in the context of current climate change policy negotiations, where new mechanisms are under discussion to address the issue of "Reducing Emissions from Deforestation and forest Degradation" (REDD). The main idea of such a REDD mechanism would be to provide incentives for developing countries to reduce deforestation and associated carbon emissions, which are greater than the entire global transport sector. Reductions in deforestation, degradation and the prevention of related carbon emissions is currently considered an effective mitigation option that could combat climate change and at the same time help to conserve biodiversity (IPCC 2007).

Any such mechanism will require the systematic measuring and monitoring of national forests and their changes (Santilli et al. 2005). Many developing countries have no or insufficient monitoring systems in place to observe their forest resources for participation in REDD. Therefore, the aim of this study was to provide an assessment of each country's current status and to recommend important next steps for capacity development to implement an accurate forest area change monitoring system over the next five years. The study also considered what would be required to progress toward higher tiers (2 or 3) of IPCC-LULUCF (Land Use, Land Use Change and Forestry) compliant carbon estimation and accounting.

For each country, the study analyzed and worked on specific areas of information:

1. Current monitoring and reporting capabilities for forest area change and carbon stocks, to quantify and report on national estimates of carbon emissions from forest change;
2. Availability of data from remote sensing data sources for annual forest area change monitoring;
3. Remote sensing capacity building recommendations;
4. Capacity building recommendations with respect to country specific REDD requirements and opportunities and carbon stock assessments, with a focus on 30 countries;
5. Recommendations for regional and global capacity building activities.

The study aims to take a global perspective on the REDD capacity development issue. All information used for this project has been derived from available worldwide data sources to allow all country circumstances to be analyzed in, as much as possible, a transparent and comparative manner. Substantial national-level capacity development for measuring and monitoring forest carbon will be required and this process should start as soon as possible to ensure that existing capacity gaps are addressed and reduced before any REDD mechanism, or interim emergency funding mechanism for forests, can be implemented.

Recommendations and conclusions are derived at the country and at the global level, with a specific focus on 30 countries suggested by The Prince's Rainforests Project (PRP) and the Government of Norway. Thus, the results should be useful for different communities interested and involved in REDD capacity development including individual countries, regional centres and expert networks, and international organizations. Although the current study considers various aspects of a national forest carbon monitoring system, it has put emphasis on the capabilities required for annual monitoring of forest area changes and the role of remote sensing technologies. Thus, further research, assessment of capabilities and capacity building efforts are required to properly address the issues of measuring carbon stocks and carbon stock changes. Also, the results are intended to provide guidance and suggestions but should be further discussed and elaborated with the individual countries before they can be used in defining or implementing specific actions.

2 Methodology

The study addressed all non-Annex I countries of the UNFCCC that are located in the humid or dry tropics; in total 99 countries. Different types of indicators were developed to assess the current capabilities and the specific challenges of each country. These indicators were built with respect to the requirements and components that are needed to establish a national REDD monitoring system (IPCC 2003, GOFC-GOLD 2008). A suite of consistent global information sources were analyzed for each country. International country reporting to FAO and UNFCCC was reviewed regarding current country monitoring capabilities. If available, further information from submissions to UNFCCC and to the World Bank Forest Carbon Partnership Facility (FCPF) have been integrated as well. In addition, a suite of global geo-data products have been used to analyze specific country conditions that will be important for developing or consolidating a national REDD monitoring system. Such information includes remote sensing technical challenges (data access and availability, cloud coverage etc.) and country-specific characteristics and opportunities related to REDD monitoring (deforestation rate, importance of degradation, biomass burning, other carbon pools etc.). The results of the assessment are used to develop country-specific recommendations for the capacity building.

2.1 Foundations for forest (carbon) monitoring

Although, the details for a REDD mechanism and an interim funding mechanism for forests are still under discussion, this study gives an overview of the capacities that are needed to implement an accurate forest area change monitoring system and comprehensive carbon emission estimation and reporting (minimum of a Tier 2 level specified by IPCC-LULUCF). The international guidelines of IPCC for LULUCF and AFOLU (Agriculture, forestry and other land uses) already provide a framework of methods (IPCC 2003, GOFC-GOLD 2008, Herold and Johns 2007). The knowledge and understanding of these methods for forest monitoring and carbon stock estimation according to IPCC GPG is a prerequisite for each country, as is the institutional framework that specifies responsibilities for different tasks within the monitoring.

Several requirements need to be considered to implement a national monitoring system. The first component – *forest area change monitoring* – needs to deliver forest area and spatially explicit forest area change, corresponding to approach 3 of IPCC guidelines for LULUCF and AFOLU. It therefore requires the application of transparent and consistent datasets. The use of remote sensing technologies is considered a suitable approach for most developing countries to assess historical and future deforestation rates (DeFries et al. 2007). The application of remote sensing techniques requires technical resources, infrastructure and human capacity for data acquisition, storage, processing and analysis and needs to consider the national circumstances. For the second component - *carbon stock and carbon stock change estimation* – the IPCC GPG provides different tiers regarding the level of detail and accuracy (Table 1).

Table 1: IPCC tiers for estimating carbon stock

Tier	Details
Tier 1	IPCC methods and IPCC default values (no data collection needed)
Tier 2	IPCC methods and country specific data for key factors (including more detailed country specific strata)
Tier 3	Country specific methods or models, national inventory of key carbon stocks, repeated measurements of permanent plots to directly measure changes in forest biomass

The application of Tier 2 requires technical resources, infrastructure and human capacity for forest inventory estimations. For Tier 3, detailed measurements of carbon stock changes need to be provided for different carbon pools (e.g. through permanent field plots).

2.2 Assessing monitoring capabilities & technical challenges

Several indicators have been used to specify the current status of forest monitoring in each country and make recommendations. Table 2 summarizes the key sources that have been identified and the information derived from each one to evaluate the current country status.

Table 2: Source of information used for this study

	Indicator	Source
Design	Involvement in UNFCCC REDD process	UNFCCC Country Submissions for REDD UNFCCC Country National Communications FCPF Readiness Plan Idea Note (R-PIN)
	Completeness of national UNFCCC reporting	Note by UNFCCC Secretariat on financial support provided by the Global Environment Facility for the preparation of national communications (UNFCCC, 2008)
	Assessment of institutional framework and capacities	FCPF Readiness Plan Idea Note (R-PIN) Country Reports for FAO Forest Resources Assessment 2005
Data collection	Remote sensing capability / Forest area time series	Country Reports for FAO Forest Resources Assessment 2005
	Data on carbon emissions in remaining forests	UNFCCC Country National Communications Country Reports for FAO Forest Resources Assessment 2005
	Emission reporting from other carbon pools	UNFCCC Country National Communications Country Reports for FAO Forest Resources Assessment 2005
Current CB	Participation in regional and international networks and REDD readiness effort	FAO National Forest Monitoring and Assessment Program GOFC-GOLD Regional Networks Global Land Cover Network FAO FRA 2010 remote sensing survey FCPF Readiness Plan Idea Note (R-PIN)
RS data	Remote sensing data availability	Coverage of Landsat 5 and CBERS receiving stations Coverage of archived SPOT (Satellite Pour l'Observation de la Terre) data and assessment of cloud-free data availability
	Data access	Broadband internet speed (speedtest.net)
	Topography	SRTM (Shuttle Radar Topography Mission) and FAO Elevation Product
	Annual cloud coverage probability	MODIS (Moderate-resolution Imaging Spectroradiometer) M3 Product (Cloud Fraction Mean)& EECRA (Extended Edited Cloud Report Archive)
General	Forest area and deforestation hot spots	MODIS Vegetation Continuous Field Product 2001 (Hansen et al. 2006) MODIS VCF (Vegetation Continuous Fields) Hot-Spots, 2000-2005 (Hansen et al. 2008)
	Forest degradation	World map of intact forest landscapes (Greenpeace, 2005) Fire: GLOBCARBON Burnt Area 2000-2008
	Carbon stocks	Aboveground/belowground: IPCC Tier-1 Global Biomass Carbon Map for the Year 2000 (Ruesch & Gibbs, 2008) Soil: Organic carbon pool (kg/m²/m) – Subsoil (FAO, 2007)
	Relevance of forest fires	GLOBCARBON Burnt Area Estimates

A major information source to assess the monitoring capabilities has been the national reporting to the FAO Forest Resource Assessment (FAO 2006) and to the UNFCCC (UNFCCC 2008). Every five to ten years, the FAO undertakes a global forest resources assessment (FRA). Participating countries have to submit detailed information concerning current status and recent trends of their national forest resources with respect to various parameters e.g. forest area, biomass, carbon stock and biodiversity – this has proven to be highly problematic for many developing countries. Within the UNFCCC, all parties are encouraged to submit national communications. In the case of non-Annex I countries, the communications shall include a national inventory of anthropogenic emissions of all GHG by sources, to the extent that the national capacities permit. Furthermore, for 25 countries,

"Readiness Project Idea Notes" (R-PIN's) are available. These documents have been prepared by countries participating in the REDD readiness initiative of the Forest Carbon Partnership Facility (FCPF) and include a detailed description of current forest monitoring and GHG estimation as well as an assessment of identified gaps and challenges. This study is based on the evaluation of these documents rather than a detailed consultation with national experts (which would be the preferred option if time and resources permitted).

Table 3: Indicators to assess current monitoring and reporting capacity

	Key requirement	Indicator	Description of categories
GHG inventory	Understanding of international UNFCCC negotiations and REDD process	Engagement in UNFCCC REDD process	Low: Only National Communication (NC) or no documented interaction Medium: NC and/or at least one REDD submission High: others and/or R-PIN
	Understanding of IPCC guidelines for reporting	Completeness of national UNFCCC reporting	Low: < 50 % Advanced: 50 - 99 % Complete: 100 %
Forest monitoring capacities	Forest area change monitoring capacity	Forest area change time series & Remote sensing capabilities	Very low: No forest cover map Limited: Forest cover map (external) Some: Multiple forest cover maps (external) Good: forest cover map in-house OR multiple maps, latest before 2000 Very Good: Regular forest area mapping most recent after 2000
	Carbon stock assessment	Forest inventory capacities (growing stock and/or biomass)	Very low: No inventory available Limited: One inventory available (produced external) Some: Multiple inventories (produced external) Good: Inventories available (in-country), before 2000 Very good: Multiple inventories (in-country), most recent after 2000
		Reporting on carbon for different pools	Low: No reported carbon stocks Limited: Aboveground biomass (AGB) reported (using Tier 1) Intermediate: Minimum AGB and soil reported (using Tier 1) Good: AGB reported (using tier 2) Very good: Various carbon pools (using tier 2)
Cooperatio	Relevant regional and international cooperation and monitoring activities	Regional and international networks and Relevant monitoring activities	FAO FRA 2010 FAO NFMA GOFC-GOLD Regional Networks GLCN (Global Land Cover Network)
Specific characteristics and requirements	Challenges for national REDD actions and monitoring	Proportion of country area with tree canopy cover > 40 %	None: 0 % Some: 1-50 % High: > 50 %
		Amount of intact forest	Low: 0 % Some: 1-50 % High: > 50 %
		Area affected by fire (in forests) on annual average 2000-2008	Low: 0 % Medium: > 0 % of land area burnt annually (on average) High: > 10 % of area with >40% tree cover burnt annually (on average)
		Carbon storage in forest vegetation	Proportion of forest with high (above- and belowground) carbon stock (>125 t/ha) [in %]
		Carbon storage in soils as proportion of forest area with high carbon soils (> 15 g/m²)	Low: 0 % Some: 1-20 % of area with >40% tree cover Large: > 20 % of area with >40% tree cover
	Remote sensing technical challenges (for annual monitoring)	Data availability	Percentage of country covered by Landsat 5/CBERS Percentage of country covered by annual, cloud-free SPOT data 2006-2008 (in archive)
		Data access	Average internet download speeds in kbps
		Topography	Percentage of country with high topography/steep slopes
		Cloud coverage	Annual cloud coverage (in percent) and seasonality

A number of available global datasets have been processed into a common format and analyzed to derive additional information on forests, forest observation data, carbon stocks and forest disturbances (Table 2). Table 3 describes the indicators that have been used to assess country characteristics and capacities with respect to key requirements for REDD monitoring. The indicators have been categorized in groups to allow for a comparative analysis on the global level.

2.3 Deriving recommendations for capacity development

The design and implementation of a monitoring system for REDD can be understood as an investment in information that is essential for successful participation in a REDD mechanism. Countries should build on existing forest data and capacities available in-country.

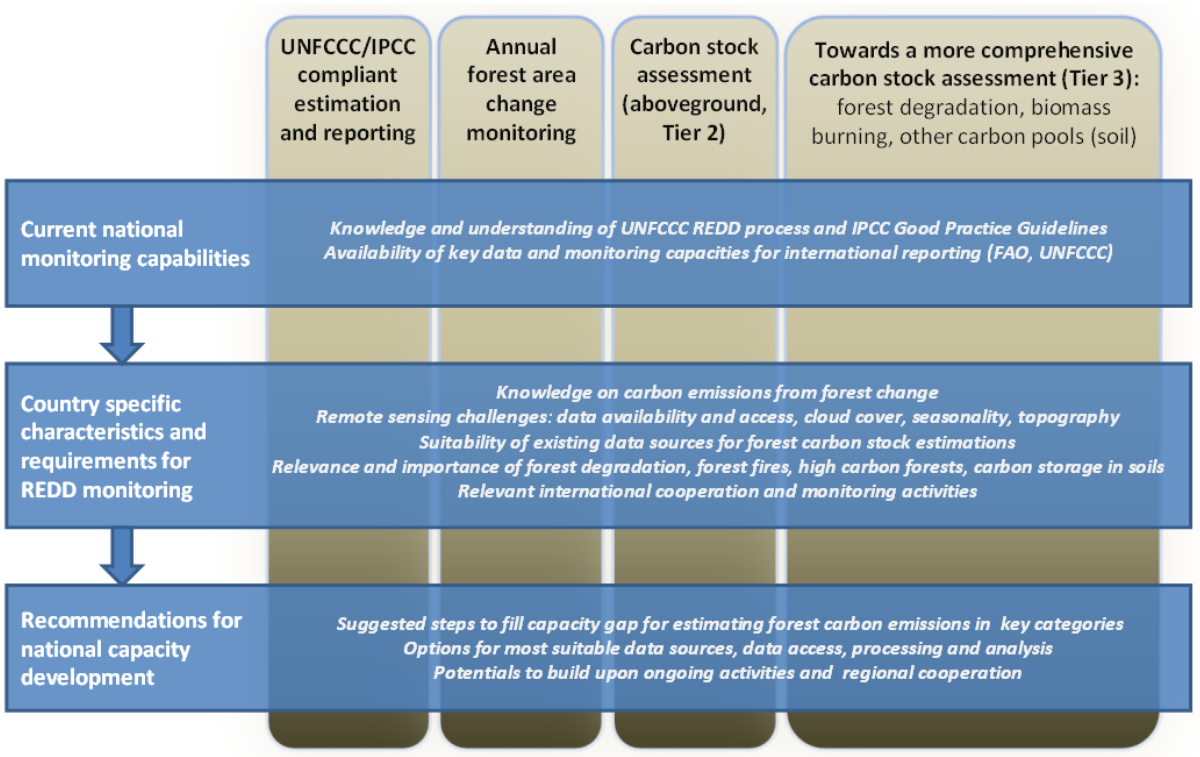

Figure 1: Conceptual framework to derive recommendations for national capacity development for this study.

As exemplified in Figure 1, the evaluation of country capacities and REDD specific characteristics provides the basis to specify the recommendations. Starting with an assessment of current capacities, additional information on country-specific characteristics and requirements for REDD have been analyzed through a number of indicators (Table 2, 3 and 4). A summary of key components and required capacities for estimating and reporting emissions and removals from forests is provided in Table 4. These components help to define the requirements that a monitoring system should include and deliver, following the requirements outlined in the IPCC GPG. The difference between the current status and the requirements provides information on the capacity gap.

Table 4: Components and required capacities for establishing a national monitoring system for REDD.

Phase	Component	Capacities required
Planning & design	1. Need for establishing a forest monitoring system as part of a national REDD implementation plan	• Knowledge on international UNFCCC negotiations and guidance for monitoring and implementation • Knowledge of national REDD implementation strategy and objectives
	2. Assessment of existing national forest monitoring framework and capacities, and identification of gaps in the existing data sources	• Understanding of IPCC LULUCF estimation and reporting requirements • Synthesis of previous national and international reporting (i.e. UNFCCC national communications & FAO Forest Resources Assessment) • Expertise in estimating terrestrial carbon dynamics, related human-induced changes and monitoring approaches • Expertise to assess usefulness and reliability of existing capacities, data sources and information
	3. Design of forest monitoring system driven by UNFCCC reporting requirements with objectives for historical period and future monitoring	• Detailed knowledge in application of IPCC LULUCF good practice guidelines • Agreement on definitions, reference units, and monitoring variables and framework • Institutional framework specifying roles and responsibilities • Capacity development and long-term improvement planning • Cost estimation for establishing and strengthening institutional framework, capacity development and actual operations and budget planning

Data collection & monitoring	4. Forest area change assessment (activity data)	• Review, consolidate and integrate the existing data and information
		• Understanding of deforestation drivers and factors
		• If historical data record insufficient – use of remote sensing:
		  ○ Expertise and human resources in accessing, processing, and interpretation of multi-date remote sensing imagery for forest changes
		  ○ Technical resources (Hard/Software, Internet, image database)
		  ○ Approaches for dealing with technical challenges (i.e. cloud cover, missing data)

	5. Changes in carbon stocks	• Understanding of processes influencing terrestrial carbon stocks
		• Consolidation and integration of existing observations and information, i.e. national forest inventory or permanent sample plots:
		  ○ National coverage and carbon density stratification
		  ○ Conversion to carbon stocks and change estimates
		• Technical expertise and resources to monitor carbon stock changes:
		  ○ In-situ data collection of all the required parameters and data processing
		  ○ Human resources and equipment to carry out field work (vehicles, maps of appropriate scale, GPS, measurements units)
		  ○ National inventory/permanent sampling (sample design, plot configuration)
		  ○ Detailed inventory in areas of forest change or "REDD action"
		  ○ Use of remote sensing (i.e. for stratification)
		• Estimation at sufficient IPCC Tier level for:
		  ○ Estimation of carbon stock changes due to land use change
		  ○ Estimation of changes in forest areas remaining forests
		  ○ Consideration of impact on five different carbon pools

	6. Emissions from biomass burning	• Understanding of national fire regime and fire ecology, and related emission for different greenhouse gases
		• Understanding of slash and burn cultivation practice and knowledge of the areas where being practiced
		• Fire monitoring capabilities to estimate fire affected area and emission factors:
		  ○ Use of satellite data and products for active fire and burned area
		  ○ Continuous in-situ measurements (particular emission factors)

	7. Accuracy assessment and verification	• Understanding of error sources and uncertainties in the assessment process • Knowledge on the application of best efforts using appropriate design, accurate data collection, processing techniques, and consistent and transparent data interpretation and analysis • Expertise on the application of statistical methods to quantify, report and analyze uncertainties for all relevant information (i.e. area change, change in carbon stocks etc.) using, ideally, a sample of higher quality information
Data treatment	8. National GHG information system	• Knowledge on techniques to gather, store, and analyze forest and other data, with emphasis on carbon emissions from LULUCF • Data infrastructure, information technology (suitable hard/software) and human resources to maintain and exchange data and quality control
	9. Analysis of drivers and factors of forest change	• Understanding and availability of data for spatio-temporal processes affecting forest change, socio-economic drivers, spatial factors, forest management and land use practices, and spatial planning • Expertise in spatial and temporal analysis and use of modeling tools
Reference emission levels	10. Establishment of reference emission level and regular updating	• Data and knowledge on deforestation and forest degradation processes, associated GHG emissions, drivers and expected future developments • Expertise in spatial and temporal analysis and modeling tools • Specifications for a national REDD implementation framework
Reporting	11. National and international reporting	• Expertise in accounting and reporting procedures for LULUCF using the IPCC GPG • Consideration of uncertainties and procedures for independent international review

The largest capacity gaps exist for countries:

- that have limited experience in estimation and reporting of national GHG inventories, for application of the IPCC GPG and with limited engagement in the UNFCCC REDD process so far;
- with low existing capabilities to continuously measure forest area changes and changes in forest carbon stocks as part of a national forest monitoring system. Reporting carbon stock changes on the IPCC Tier 2 level is considered a minimum requirement;
- that face particular challenges for REDD implementation, i.e. they have high current deforestation rates, significant emissions from forest degradation or biomass burning and soil carbon stocks that are currently not measured on a regular basis;
- where the availability of useful data sources for forest monitoring are constrained. In this study the focus on the availability of common satellite data sources (i.e. Landsat, SPOT, CBERS) that may be limited in their use due lack of receiving stations, persistent cloud cover, seasonality issues, topography or inadequate data access infrastructure.

Based on existing capacity gaps, this study has derived recommendations for capacity development (Figure 1). Recommendations will be made on two levels: (a) recommendations for a world-wide, comparative assessment for 99 non-Annex I countries in tropical regions and (b) detailed recommendations for a selection of 30 countries.

3 Results and recommendations

3.1 Overview of existing country capacities

An assessment of existing information and current capacity is the foundation for each country when designing and implementing its forest carbon monitoring systems. The development of UNFCCC national communications has stimulated countries to establish national GHG inventories and related national estimation capacity. Figure 2 highlights the current status and the range of completeness for national GHG inventories for the countries studied in this project. Less than 1/5 of tropical non-Annex I countries are listed with a fully developed inventory. Of the 99 countries, 50 countries have taken significant steps, with inventories in the range of 50-100% complete. About half of the countries currently have systems less than 50% complete. Although the information in Figure 2 refers to the establishment of full GHG inventories, where the LULUCF sector is only one component, Figure 2 provides a sense of the current capacity gap for national-level GHG estimating and reporting using IPCC guidelines or GPG.

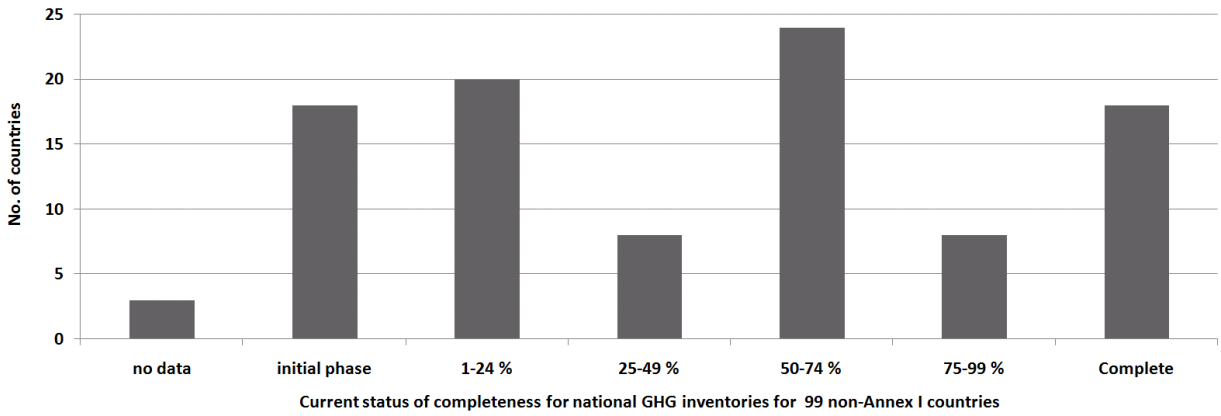

Figure 2: Status for completing national greenhouse gas inventories as part of Global Environment Facility support for the preparation of national communications of 99 non-Annex I tropical and sub-tropical countries (UNFCCC, 2008).

In terms of monitoring changes in forest area, Figure 3 highlights that almost all 99 non-Annex I countries were able to provide estimates of forest area and changes in forest area. About 75% of the countries provided this information based on multi-date data and about one quarter reported based on single-date data. Most of the countries used data from the year 2000 or before as their most recent data point for forest area, while 29 of the 99 countries were able to provide more recent estimates. Of the countries that used multi-date information, remote sensing has been the most prominent source of information. Field surveying and mapping and expert estimates are also common (Note: Countries may have used multiple sources for reporting such data to the FAO).

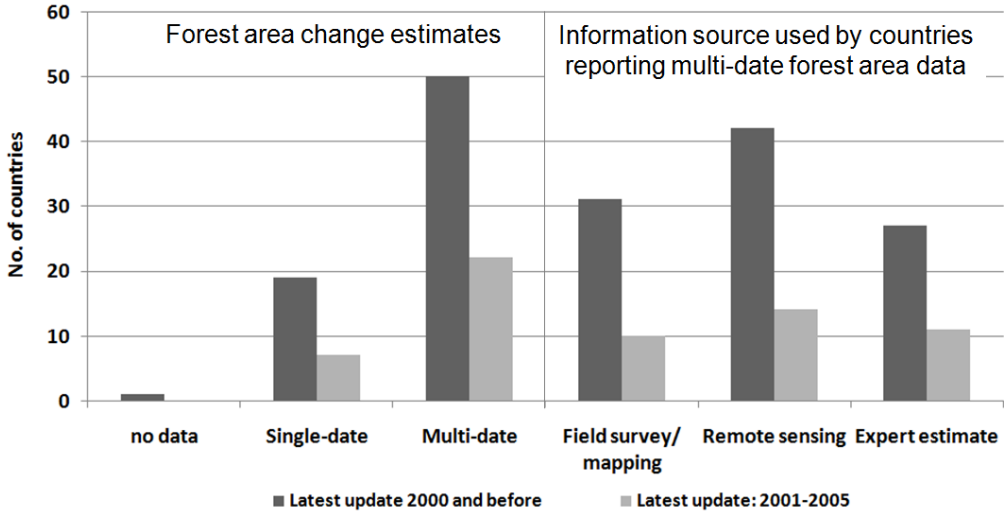

Figure 3: Summary of data and information sources used by 99 non-Annex I tropical and sub-tropical countries to report on forest area change for the FAO FRA 2005 (FAO 2006). Note: single date estimates are based on assumptions (i.e. a multivariable model including population growth).

A number of countries provided estimates for carbon stocks (Figure 4). 71 of the 99 countries reported on the overall stocks in above ground carbon pools. Since the above ground and below ground carbon pools are correlated, almost the same number of countries reported on the carbon in below ground vegetation. Fewer countries were able to provide data on the other pools, in particular for carbon in the soil (12 countries). The reported forest carbon pool estimates are primarily based on growing stock data as the observation variable. A number of different information sources are applied by countries for converting growing stocks to biomass (and to carbon in the next step), with the IPCC GPG default factors being used most commonly (Figure 4). Only 11 countries converted growing stock to biomass using specific and, usually, national conversion factors.

Given the results of this assessment, the majority of the countries have limitations in providing a complete and accurate estimation of GHG emissions and forest loss. Some gaps in the current monitoring capabilities can be summarized according to the relevant reporting principles:

- **Consistency:** Estimations previously provided by many countries are based either on single-date measurement or on integrating heterogeneous data sources, rather than using a systematic and consistent measurement and monitoring approach;
- **Transparency:** Expert opinions, independent assessments or model estimations are commonly used as information sources to produce forest carbon data; this could potentially lead to a lack of transparency;
- **Comparability:** Common methodologies and guidance must be used to produce comparable results. Few countries have experience in using the IPCC GPG as a common approach to estimation and monitoring;

- **Completeness:** The lack of suitable data for measuring and monitoring forest area change and changes in carbon stocks in many non-Annex 1 countries is evident. Carbon stock data for above ground and below ground carbon are often based on estimations or conversions using IPCC default data and very few countries are able to provide information on all five carbon pools or estimates from biomass burning.
- **Accuracy:** There is limited information on sources of error and uncertainty levels of the estimates provided by countries, and approaches to analyze, reduce, and deal with these in international reporting

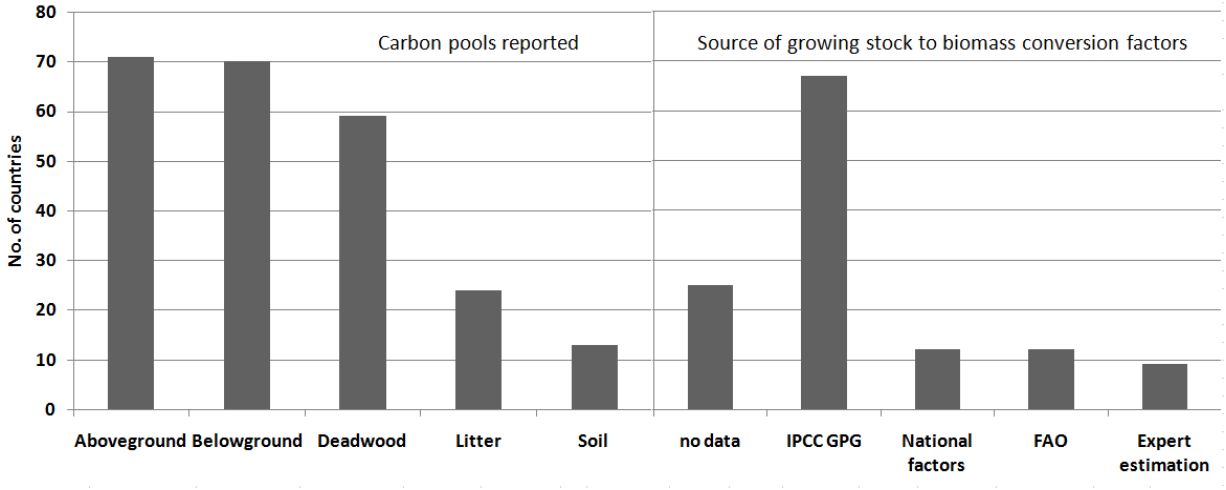

Figure 4: Summary of data for five different carbon pools reported (left) and information sources used by 150 non-Annex I countries to convert growing stocks to biomass (right) for the FAO FRA 2005 (FAO 2006, countries may have used multiple sources for the conversion process).

3.2 Recommendations for national level capacity building

3.2.1 General suggestion for capacity building in 99 countries

Appendix A lists a number of indicators derived for this study that provide the foundation for countries to assess their existing capacities and specify the next steps to improve their monitoring systems. The indicators should be considered with the flowchart presented in Figure 5. This flowchart lists the pathways and indicative cost implications for countries and requires an understanding of the capacity gap between what is needed for such a system and the status of current monitoring capacities (see Table 4 and Appendix A). Using this information, countries may use the flowchart to guide them through a number of the key components (in Figure 5) that need to be considered and addressed during capacity development.

The first step for building national monitoring capacity should specify the monitoring objectives and implementation framework, based on the understanding of:

- Guidance for monitoring and implementation provided under the UNFCCC;
- Monitoring should be part of the national REDD implementation strategy and objectives;
- Knowledge in the use and application of the methods of IPCC LULUCF good practice guidelines;
- Existing national forest monitoring capabilities;
- Expertise in estimating terrestrial carbon dynamics and related human-induced changes;
- The consideration of different requirements for monitoring forest changes historically (reference period) and for the future (accounting period).

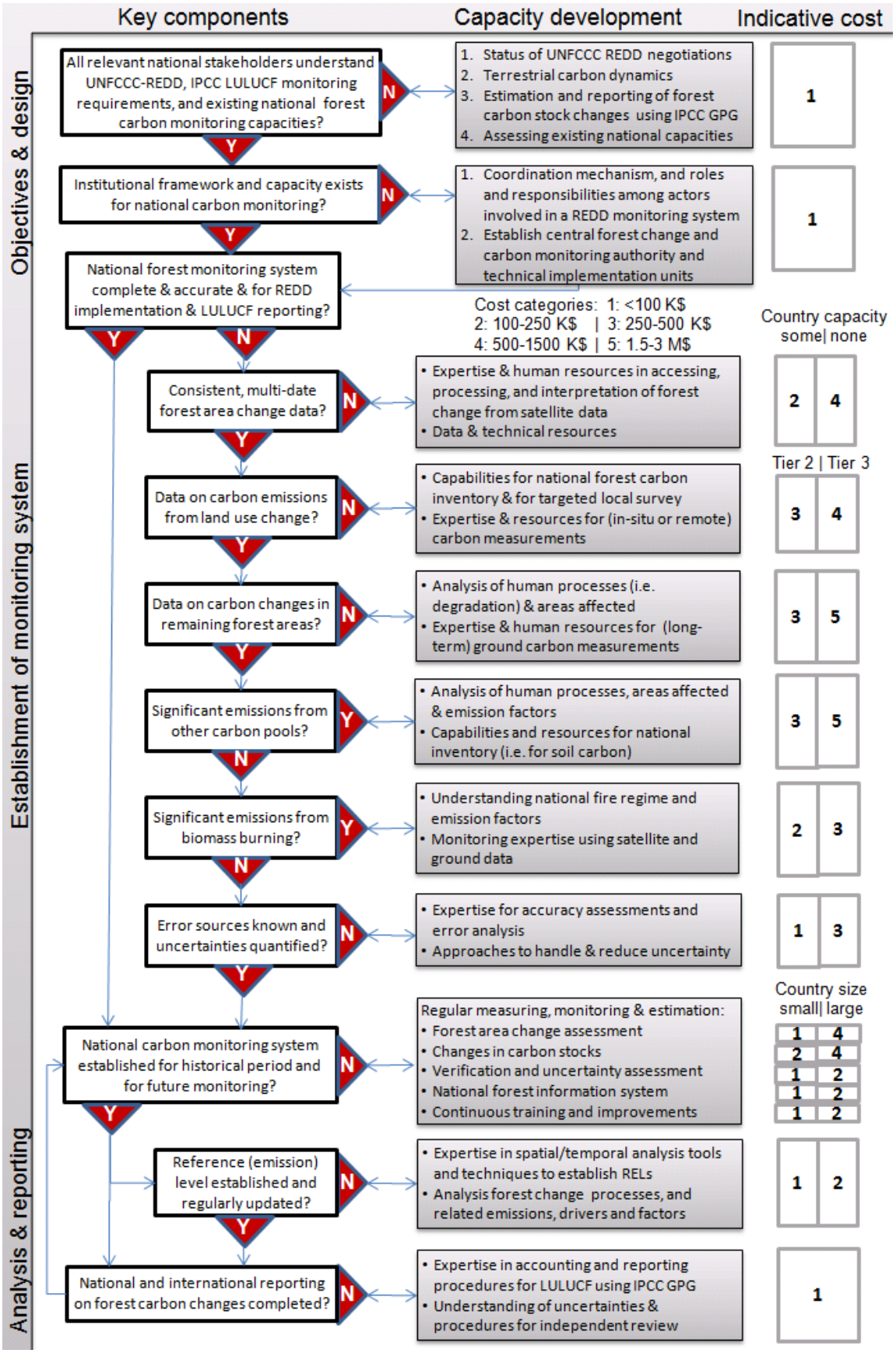

Figure 5: Flowchart for the process to establishing a national monitoring system linking key components and required capacities (see Table 4), and indicative cost category estimates.

The initial planning and design phase should result in a national forest carbon monitoring system (incl. definitions, monitoring variables, institutional setting etc.), and a plan for capacity development, long-term improvement and anticipated costs.

Appendix A lists the completeness of the national GHG inventory and the current country engagement in REDD as indicators to be considered in addition to the existing institutional capacities to decide how much capacity development would be required for the planning and design phase. A suitable degree of organizational capacity within the country is required to establish and operate a national forest carbon monitoring program. Activities include acquisition of different types of data, analysis, estimation, international reporting, and the use of forest data. Different actors and sectors will need to be working in coordination to make the monitoring system efficient in the long-term.

Table 5: Summary of country capacities for forest area change monitoring and forest inventories determined from the data sources used in this study.

		Forest area change monitoring capacities					
		very low	*Limited*	*some*	*good*	*very good*	*SUM*
Forest inventory capacities	*very low*	19	3	6	8	3	39
	limited	13	3	6	7	2	31
	some	1	0	2	0	0	3
	good	4	7	2	5	3	21
	very good	1	0	0	1	3	5
	SUM	38	13	16	21	11	99

General area change recommendations for 99 countries

Table 5 summarizes the existing country monitoring capacities as determined by this study. The table emphasizes that capacities are less established for forest inventories (used to derive carbon stock estimates) than for forest area change monitoring. For forest area change monitoring, countries with none, limited or some existing capabilities (marked light red in Table 5) require the development of basic capacities. For these countries the recommendation is to make use of remote sensing data to consistently monitor historical and future forest area changes. Such efforts require:

- Expertise and human resources in accessing, processing, and interpretation of multi-date remote sensing imagery for forest changes;
- Use of free global Landsat and CBERS data (most suitable data option; additional data sources can be provided by SPOT and others);
- Technical resources are needed: hardware/software, suitable remote sensing data access procedures (may be limited by current internet speeds), image database archive;
- Approaches for dealing with technical challenges: cloud cover, seasonality, topography (Appendix A indicates whether technical remote sensing challenges maybe an issue);
- Expertise in IPCC compliant area change estimation from monitoring data and products.

Approaches for accuracy assessment, understanding of error sources and uncertainties for building and improving the monitoring system should be built into the system from the beginning. For countries with good to very good foundations for area change monitoring (Table 5), the following options should be considered:

- Review, consolidate and integrate existing data and information into consistent time-series;
- Perform an accuracy and consistency assessment to understand and quantify error sources and specify steps for improving the monitoring (data sources and methodology);
- Ensure proper use of information for IPCC GPG-compliant area change estimation and reporting;

- Perform assessment for the expansion of forest change assessment using remote sensing to annual monitoring;
- Use existing data for the analysis and understanding of deforestation drivers and factors;
- Potentially engage in South-South cooperation and technology transfer for building capacities in countries with lower capacities.

General carbon measurement recommendations for 99 countries

For countries with low forest inventory capacities (marked red in Table 5), a national forest carbon inventory needs to be established. Therefore, the implementation of human and technical resources is needed for field work and measurements as well as for the data interpretation and analysis. The near-term objective would be the establishment of a national forest carbon inventory on Tier 2 level (covering at least the above ground carbon pool), which requires:

- Development of a sampling design and national stratification for carbon density
- Human resources and equipment to carry out field work on a sustained basis
- Implementation of field sample plots to derive the following parameters:
  - National inventory/permanent sampling (sample design, plot configuration)
  - In-situ data collection of all the required parameters and data processing
  - Allometric data (for biomass conversion and expansion)
  - Carbon fraction values considering country-specific stratification
- Disturbance matrices tracking transfers between carbon pools (if required)

A significant number of countries already maintain forest inventories. However most of the existing and traditional forest inventories have not been designed for carbon stock assessments. Ideally, and in contrast to traditional inventories, the design for a national carbon stock inventory should consider requirements that would help to make best use of existing data, or efforts to improve the measurements towards a national forest carbon stock inventory:

- Stratification of forest area by carbon density classes and relevant human activities affecting forest carbon stocks;
- Aim for full national coverage (if desired) with most detail and accuracy required in areas of "REDD relevant activities";
- Site measurement of carbon stocks, potentially in all key carbon pools—i.e. those containing quantities of carbon that would significantly change in response to deforestation, degradation or enhancement;
- Time series; consistent and recurring measurements of carbon stock change, i.e. for deforestation and in areas remaining as forests (degradation);
- Quantification of uncertainties for verification and considerations for independent international review.

In general, the analysis and use of existing data is most important for estimating historical changes and for the establishment of reference emission levels. Limitations of existing data and information may constrain the accuracy and completeness of the information to be reported for historical periods, i.e. for lack of ground data. In case of uncertain or incomplete data, the estimates should follow, as much as possible, the IPCC reporting principles and should be treated conservatively with motivation to improve the monitoring over time. The monitoring and estimation activities for the historical period should include a process for building the required capacities within the country to establish the monitoring, estimation and reporting procedures as a long-term term system. Consistency between the estimates for the historical period and future monitoring is essential, the existing gaps and known uncertainties of the historical data should be addressed in future monitoring efforts as part of a continuous improvement and training program.

Depending on the country characteristics, the required investments and priority setting for monitoring carbon stock changes across all carbon pools (i.e. soils, biomass burning) may depend on

how significant the related human-induced changes are for the overall carbon budget and the national REDD implementation strategy. For example, if the country has no fire regime and no significant emission from biomass burning it is not necessary to develop related monitoring. Thus, the decision on how and when a country would move from a Tier 2 level carbon stock assessment (considered as a minimum near-term target) to more detailed and accurate Tier 3 estimation and reporting, depends on the country circumstances, existing capacities, and the evolving national REDD implementation objectives. Figure 6 illustrates a number of maps indicating where particular attention should be paid to REDD and carbon related issues for national monitoring. The maps illustrate regions with:

- Fire and biomass burning being a significant issues,
- Areas with significant amounts of soil carbon,
- Large amounts of intact forests that show no sign of significant human intervention,
- Areas of remaining forest cover with more than 40% tree canopy cover,

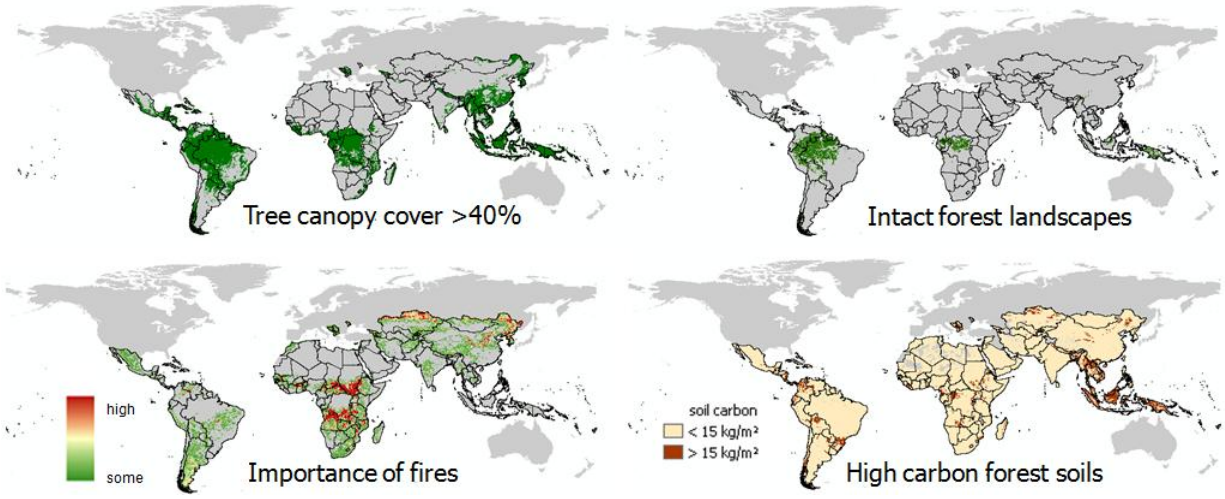

Figure 6: Overview of some REDD related issues with relevance for monitoring.

If fires and high-carbon soils are present within a country, this should be considered when specifying the detail and focus of the monitoring system, i.e. it should be evaluated for each country case whether monitoring forest fires and soil carbon is a required or a suitable option to achieve significant emission reductions. There is no need to impose blanket monitoring requirements for all countries, in particular for initial efforts to establish minimum level capacities. However, all carbon pools, and drivers and processes impacting forest carbon should be evaluated eventually and, if significant, included in a national monitoring system and the national REDD strategy, helping to maintain the terrestrial carbon reservoir.

For forest degradation, countries with large amounts of forest cover but low amounts of intact forest are indicative of ongoing processes that are disturbing existing forest areas. The monitoring of carbon changes in forests remaining as forests (both increase and decrease) is generally less efficient than monitoring of deforestation, i.e. lower carbon stock changes per ha versus higher monitoring costs and, usually, lower accuracy. On the other hand, monitoring of forest degradation is important since the cumulative emission can be significant and updated data are required to avoid displacement of emissions from reduced deforestation. A country should understand and regularly monitor the human processes causing increases or decreases in forest carbon stocks, i.e. through a recurring assessment of degraded forest area. However, the level of detail and accuracy for actual carbon stock changes should be higher for countries interested in claiming credits for their activities (i.e. reducing emissions from forest degradation). In this case, the establishment of the REDD monitoring system should put particular emphasis on building the required capacities, which usually

require long-term, ground-based measurements. A similar procedure may be suggested for the monitoring of changes in other carbon pools.

To date, very few developing countries report data on soil carbon, even though emissions may be significant, i.e. emissions from deforested or degraded peatlands. If the soil carbon pool is to be included in country strategy to receive credits for reducing emissions from forest land, the related monitoring component should be established from the beginning to provide the required accuracy for estimation and reporting. For other countries, the monitoring of emissions and removals from all carbon pools and all categories is certainly encouraged in the longer-term, but may be of lower priority and require smaller investment of resources in the readiness phase. This approach is supported by the current IPCC guidance which already allows a cost-effective use of available resources. For example, key categories (according to the IPCC-GPG) are sources of emissions/removals that contribute substantially to the overall national inventory (in terms of absolute level and/or trend) and priority should be given to the most relevant categories and/or carbon pools. This flexibility can be further expanded by the concept of conservativeness. Conservativeness is a concept used by the provisions of the Kyoto Protocol (UNFCCC 2006). In the REDD context, conservativeness may mean that - when completeness or accuracy of estimates cannot be achieved - the reduction of emissions should not be overestimated, or at least the risk of overestimation should be minimized (Grassi et al., 2008).

Implementing measurement and monitoring procedures to obtain basic information to estimate GHG emissions and forest loss requires capabilities for data collection for a number of variables. Irrespective of the choice of method, the uncertainties of all results and estimates need to be quantified and reduced as far as practical. A key step to reduce uncertainties is the use of best efforts with suitable data sources, appropriate data acquisition and processing techniques, and consistent and transparent data interpretation and analyses. Expertise is needed for the application of statistical methods to quantify, report and analyze uncertainties, the understanding and handling of error sources, and approaches for continuous improvement of the monitoring system both in terms of increasing certainty for estimates or for a more complete estimation (i.e., including additional carbon pools).

All relevant data and information should be stored, updated, and made available through a common data infrastructure, that is, as part of a national GHG information system that will need to be developed. The information system should provide the basis for the transparent estimation of emissions and removals of GHG and be able to provide data in a spatially-explicit and transparent format. The information system should also help in analysis of data (i.e., including information that may help in determining the drivers of forest change), support national and international reporting, and in the implementation of quality assurance and quality control procedures, followed by an expert peer review.

3.2.2 Detailed recommendations for a selection of 30 countries

The general recommendations for country capacity building described in section 3.2.1 have been further defined for 30 countries. Appendix B provides the detailed recommendations for the countries for activities suggested for the next few years to achieve a minimum level of monitoring, make best use of existing data resources and take advantage of available data sources and methods internationally (i.e. remote sensing). They have been derived from the variety of information and data sources specified in Table 2 and include recommendations on infrastructure, human resources, forest area change monitoring, and carbon measurements. Table 6 summarizes the current status of capacities for forest area change monitoring and forest inventories. The variability of existing capabilities has resulted in country specific recommendations on how to improve on existing data and information to improve the system in the coming years.

Table 6: Summary of country capacities for monitoring forest area change and forest inventories for a selection of 30 countries.

Forest inventory \ Forest area change monitoring	No forest cover map	Forest cover map (external)	Multiple forest cover maps (external)	forest cover map in-house OR multiple maps, latest before 2000	Regular forest area mapping most recent after 2000
No consistent national field inventory			Paraguay Tanzania	Congo Ecuador Nepal	Bolivia Colombia Malaysia
One national inventory (external)	Guyana CAR Gabon Nigeria Kenya	Zambia	Liberia	Ghana Panama	Costa Rica Brazil
Multiple inventories (external)			DR of Congo PNG		
One or more Inventories available (in-country), most recent before 2000		Cameroon Suriname	Madagascar	Laos	Indonesia Peru Vietnam
Regular forest inventories (in-country), most recent after 2000					India Mexico

Only Brazil (Amazon region) and India currently perform an annual or bi-annual wall-to-wall monitoring using remote sensing data. Since annual monitoring is a potential objective for some countries and regions, Figure 7 provides some indication of the availability of current remote sensing data for such purposes. The first diagram (blue and red bars in Figure 7) shows that not all the countries are fully covered by Landsat 5/CBERS receiving stations; hence there currently is no sustained access to free-of-charge data from these sensors for all countries. SPOT data should be able to provide a suitable alternative. However, a cloud-free annual coverage for three independent years 2006, 2007 and 2008 is not available for all countries either. The SPOT data availability shown in Figure 6 is based on the actual SPOT archive and uses a rather strict selection criterion of cloud-free full annual coverage. There may well be full national cloud-free coverage if multi-year (i.e. bi-annual) SPOT data are considered, or a sampling approach is applied, or the SPOT acquisition strategy is specifically targeted towards forest monitoring issues in the tropics (this is only partially the case at this point). Perhaps there are also a number of additional optical satellite data sources available but currently not in common use for forest change monitoring in developing countries (GOFC-GOLD, 2008).

The bottom diagram in Figure 7 emphasizes a constraint for using optical remote sensing data in some countries. In particular in countries with a mean annual cloud cover of more than 80% it may become challenging to obtain a suitable and full annual coverage with current systems. For these countries, the use of Radar remote sensing satellite sources would be recommended in synergy with available optical data to achieve a full annual coverage. However, the use of Radar remote sensing data remains problematic for now (with respect to availability and cost), but may become more feasible as agencies operating Radar remote sensing satellites improve coverage and accessibility to observations (i.e. as part of GEO task). The issue of seasonality may be important in terms of high cloud coverage in some parts of the year and the fact that phenological vegetation changes (i.e. deciduous forests) can complicate the forest change monitoring.

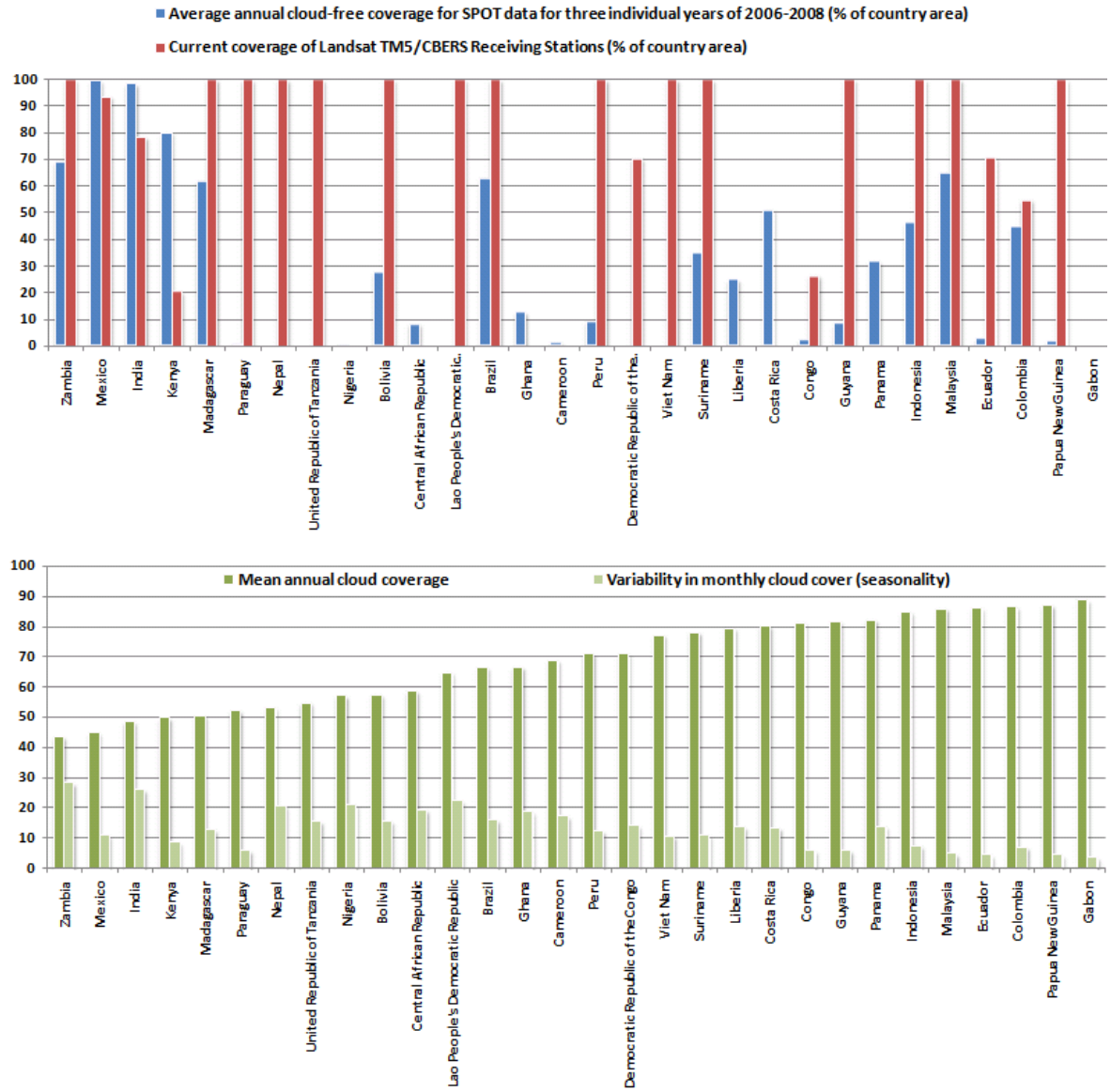

Figure 7: Availability of annual cloud free SPOT satellite data, coverage of Landsat 5/CBERS receiving stations, and cloud cover and seasonality characteristics presented for 30 countries.

3.3 Implications for international efforts

3.3.1 Remote sensing data availability and access

Currently, archived Landsat data is the most common satellite dataset used for forest monitoring at the national level. Several factors are responsible for this, including rigorous geometric and radiometric standards, the image characteristics most known and useful for large-area land-cover mapping and dynamics studies, and the user-friendly data access policy. In addition, SPOT and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data have also been used since near-global archived observations exist, but the cost is higher. For future monitoring, different satellite sensor options are available. Alternative sources of optical remote sensing data include ASTER, SPOT, IRS (Indian Remote Sensing Satellite), CBERS or DMC (Disaster Monitoring Constellation) data that vary in terms of cost and availability. For example, SPOT satellite data are considered rather expensive, but SPOT is commercially running 3 satellites and provides a comprehensive archive of data with a significant number of countries already being covered with

annual cloud-free data for the most recent years – a coverage that can be increased with targeted observation strategies using the full set of existing space assets.

Despite the suite of available satellite sensors, Figure 8 highlights some of the challenges that countries may face when using them for REDD monitoring purposes.

Figure 8 emphasizes that technical challenges complicating the use of remote sensing (persistent cloud cover, seasonality, topography) vary for different regions of the world and should be considered on a country by country or regional basis. The coverage of Landsat 5 receiving stations emphasizes a current gap in covering some regions including the center and west of tropical Africa, and Central America. SPOT would be able to provide annual coverage if focused observations and monitoring strategies are implemented. Redundancy is important and efforts should be taken to fill the current receiving station gap. Radar data such as ALOS (Advanced Land Observing Satellite) should soon be able to provide additional coverage for persistently cloudy areas.

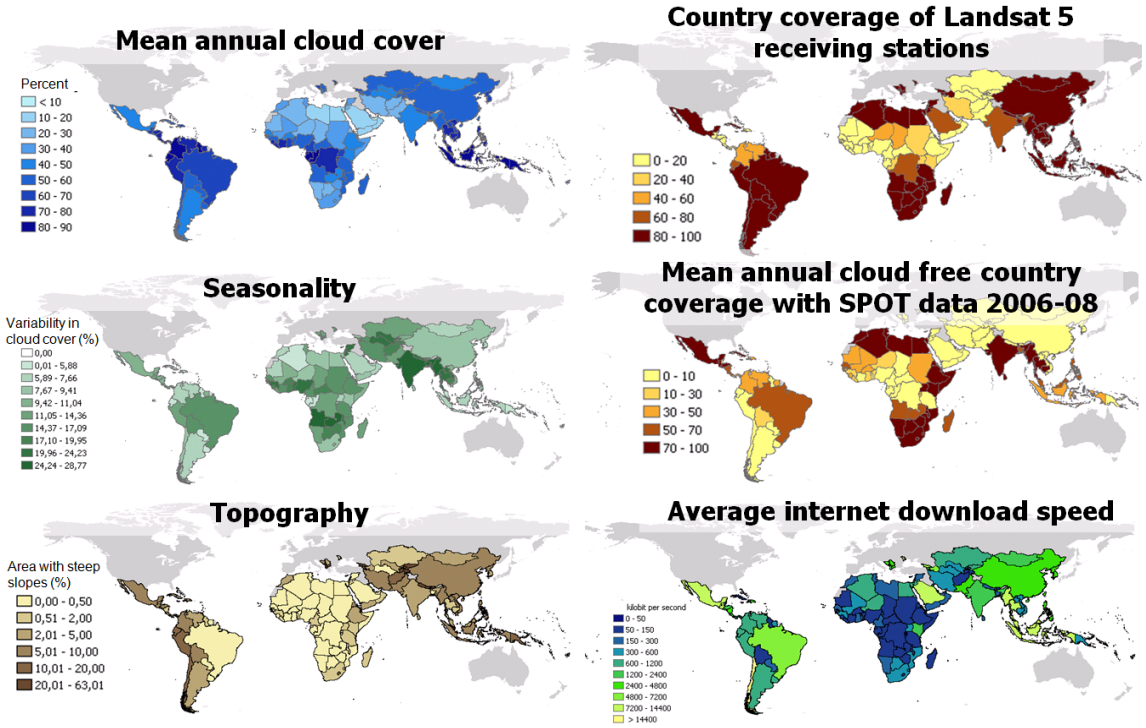

Figure 8: Technical challenges associated with the use of remote sensing data for forest monitoring.

Although some remote sensing datasets are available "free of charge", there are additional resources required to get the data ready for the interpretation and analysis of forest area change. The most common procedure to access archived satellite data is through the internet. Some countries may experience difficulties due to the low available bandwidth and therefore alternative means of data delivery need to be arranged (i.e. through regional centres, mailing hard-discs or DVD's) or the related infrastructure needs to be improved. Figure 8 shows the areas with low bandwidth that would experience limitations in accessing national coverage of satellite on a continuous basis.

In addition, all remote sensing data need to be pre-processed for interpretation. Such steps include geometric and radiometric corrections (for details see GOFC-GOLD 2008). Besides archived Landsat data that are provided as ortho-rectified image products, other remote sensing data are not routinely processed (without additional cost) to this level of geometric accuracy. Additional resources are needed to perform the required corrections using available standardized techniques and the international community may significantly reduce processing efforts for countries if higher-

level pre-processed products are made commonly available. To date, only Landsat and (to some extent) SPOT provides a suitable and internationally accepted level of standardized pre-processing for large area coverage.

The international earth observation community is aware of the need for pre-processed satellite data in developing countries. The gap between acquiring satellite observations and their availability (in the archives) and processing the data in a suitable format to be ready for use by developing countries for their forest area change assessments is being bridged by the space agencies and data providers such as USGS, NASA, ESA, JAXA, INPE, and the international coordination mechanism of CEOS (Committee on Earth Observation Satellites), GOFC-GOLD and GEO (Group of Earth Observation). In the next few years, these efforts will further decrease the level of cost and effort required to use satellite observations for national-level REDD monitoring. However, activities could be strengthened and fostered to deliver full global coverage of suitable remote sensing data. There is not necessarily a lack of data from remote sensing, bur rather a lack of coordination and data availability in developing countries that is currently preventing the full use of remote sensing for REDD monitoring.

In summary, there is a set of recommendations that would help to quickly and significantly improve the forest monitoring situation:

- Provide resources and support for ongoing activities for coordinated global forest observations through established international mechanisms;
- Improve the satellite data coverage through investing in additional receiving stations in particular in Central and West Africa and Central Latin America;
- Implement regionally-specific and coordinated observation strategies to overcome specific challenges such as persistent cloud cover, data access limitations and lack of pre-processed data for annual coverage of all countries;
- Ensure that suitably pre-processed observation products are made available to countries;
- Engage with relevant actors to ensure long-term continuity of observations for key global observation programs, e.g. NASA/USGS, ESA/EC, JAXA and INPE.

3.3.2 Options for regional cooperation

Some of the resources required to build monitoring capacity in a country are independent of the size of the area to be monitored, because a minimum level of technical resources and capacities must be met. Thus, the investments in national capacity building efforts are likely to be relatively larger for small countries with low initial capacities. For such countries, the possibility of sharing regional capacity is an option (Table 7). Regional efforts usually cost little more than the cost of the national capacity for one (small) country in terms of technical and office resources and human capital. This may include a range of opportunities for both the area change and carbon stock assessments. The cost of accessing, processing and analyzing remote sensing data can be reduced by a regional approach. There are, however, extra costs involved for establishing regional cooperation and efforts should build upon existing networks and cooperation activities to minimize the amount of resources required for this.

In many countries, some type of regional cooperation already exists and can be built upon for this purpose. The FAO FRA has long-term expertise working with countries and is currently conducting a number of regional capacity-building workshops for countries as part of its global remote sensing survey[1]. In Central Africa, there is already an established partnership among the Central African countries called COMIFAC.[2] In addition, GOFC-GOLD[3] is working on forest and land cover

[1] www.fao.org/forestry/fra2010-remotesensing/en/

[2] COMIFAC – http://www.biodiv.be/comifac2

[3] http://www.fao.org/gtos/gofc-gold/

monitoring and related capacity-building (i.e. technical expertise, improved data access, validation) with six regional networks in different regions including Africa, Southeast Asia and Latin America.

Table 7. Opportunities for regional cooperation and capacity development to reduce costs and efforts for national forest carbon monitoring.

Regional capacity	**Opportunity for reducing costs & efforts**
Centralized access and pre-processing of key remote sensing datasets for national analysis and estimation of forest area change	Reduce cost for data access and pre-processing, while interpretation may still be done within country
Establish regional remote sensing data interpretation facility	Reduce costs for technical/office resources and human resources
Regional processing and analysis of coarse resolution satellite data for near real-time detection of forest fires and deforestation	Increase availability of and reduce costs on useful data and observations
Focal point for technical capacity-building for forest monitoring in the region	Reduce costs for continuous training, technical support, and foster South-South cooperation
Support for verification and independent accuracy assessments	Standard procedures for transparent and independent verification of results
Standardization of methodologies for LULUCF estimation and reporting	Inter-regional exchange of results and experiences, and integration with carbon crediting / reducing transaction costs

There is also great potential for some of the non-Annex I countries with suitable existing capacities (e.g India, Brazil, Mexico) and long experience on conducting forest inventory and monitoring to engage in regional cooperation and South-South capacity development. Some of these processes have already started and should be further strengthened and encouraged by the international community. Some promising areas where, for example, regional cooperation would be a suitable option are in different regions of Africa (i.e. Central Africa), Latin America, South Pacific, Mekong river countries, and other Central Asian and South-East Asian countries.

It should be noted that the current study considers various aspects of a national forest carbon monitoring system, but has put emphasis on capacity required for annual monitoring of forest area changes and the role of remote sensing technologies. As indicated in the previous section, capabilities are less established for carbon stock measurement than for forest area change. Further research and capacity building efforts are required to properly address the issues of measuring carbon stocks and carbon stock changes. Such efforts currently rely on ground-data collected by a number of actors (national inventories, forestry companies, community-based measurements etc.) and will require significant development to produce and use consistent and continuous measurements of forest carbon as part of a national estimation and reporting system.

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Appendix A: Country-specific indicators

The indicators derived for this study provide the foundation for countries to assess their existing capacities and to specify the next steps for improving their monitoring system for participation in REDD, or in an intermediate funding mechanism, such as the one currently being debated in the International Working Group - Interim Financing for REDD (IWG-IFR). The indicators are described in Table 3 and should be considered with the flowchart presented in Figure 5.

Country	Engage-ment in UNFCCC REDD process	Complete-ness of GHG inventory	Forest area change monitoring capacity	Forest inventory capacity	Remote Sensing technical challenges	Proportion of tree canopy cover > 40%	Amount of intact forest	Importance of fire/ biomass burning	Carbon storage in forest soils
Angola	low	low	very low	limited	low	medium	some	medium	some
Antigua & Barbuda	low	low	very low	very low	medium	low	none	low	large
Argentina	high	complete	good	good	low	low	some	medium	some
Bahamas	medium	advanced	very low	limited	medium	medium	none	low	some
Bangladesh	low	low	limited	good	low	low	none	low	some
Belize	high	complete	good	very low	high	high	some	low	some
Benin	low	low	limited	very low	low	low	none	medium	large
Bhutan	low	low	some	good	low	high	some	medium	large
Bolivia	high	advanced	good	very low	low	high	some	medium	some
Botswana	medium	advanced	good	limited	low	low	none	high	low
Brazil	high	advanced	very good	limited	low	high	high	medium	some
Burkina Faso	medium	advanced	very low	good	low	low	none	medium	low
Burundi	high	complete	very low	very low	low	low	none	medium	large
Cambodia	medium	advanced	good	limited	low	medium	some	medium	large
Cameroon	medium	low	limited	good	medium	high	some	medium	some
Cape Verde	low	low	very low	very low	high	low	none	low	low
Central African Republic	medium	low	very low	limited	medium	high	some	high	some
Chad	low	low	very low	limited	medium	low	none	high	low
China	medium	low	very good	very good	medium	low	some	medium	some
Colombia	medium	advanced	good	very low	medium	high	high	medium	some
Comoros	low	low	limited	good	medium	high	none	low	some
Congo	high	complete	good	very low	medium	high	high	medium	large
Costa Rica	high	complete	very good	limited	high	high	some	low	large
Côte d'Ivoire	high	complete	good	limited	medium	low	some	medium	some
Cuba	low	low	very low	good	low	medium	some	low	some
Dem. Republic of Congo	high	advanced	some	some	medium	high	some	medium	some
Dominica	medium	advanced	very low	very low	high	high	none	low	large
Dominican Republic	medium	complete	very low	very low	high	medium	some	low	some
Ecuador	medium	advanced	good	very low	medium	medium	some	medium	some
El Salvador	low	low	good	very low	high	medium	none	low	some
Equatorial Guinea	low	low	very low	limited	medium	high	some	low	large
Eritrea	medium	advanced	very low	very low	low	low	none	medium	low
Ethiopia	low	low	good	very low	medium	low	some	high	large
Fiji	low	low	very low	very low	high	no Data	none	low	low
Gabon	high	low	very low	limited	medium	high	some	medium	some
Gambia	high	complete	limited	limited	high	low	none	medium	large
Ghana	high	advanced	good	limited	medium	low	none	medium	some
Guatemala	low	low	good	limited	high	high	some	medium	large
Guinea	low	low	very low	very low	low	low	none	medium	some
Guinea-Bissau	high	complete	some	very low	medium	low	none	medium	some

Country	Engage-ment in UNFCCC REDD process	Complete-ness of GHG inventory	Forest area change monitoring capacity	Forest inventory capacity	Remote Sensing technical challenges	Proportion of tree canopy cover > 40%	Amount of intact forest	Importance of fire/ biomass burning	Carbon storage in forest soils
Guyana	medium	low	very low	limited	low	high	high	low	some
Haiti	medium	advanced	very low	very low	medium	low	none	low	some
Honduras	high	complete	very low	very low	high	high	some	low	large
India	high	low	very good	very good	low	low	some	medium	large
Indonesia	medium	advanced	very good	good	medium	high	some	medium	large
Jamaica	high	complete	good	limited	medium	high	none	low	some
Kenya	medium	advanced	very low	limited	medium	low	none	medium	large
Lao	low	low	good	good	low	high	some	low	large
Lesotho	medium	advanced	some	very low	low	low	none	high	low
Liberia	high	complete	some	limited	medium	high	some	low	large
Madagascar	high	complete	some	good	low	low	some	medium	large
Malawi	low	low	limited	limited	low	low	none	medium	some
Malaysia	medium	advanced	very good	very low	medium	high	some	medium	large
Mali	low	low	very low	very low	low	low	none	high	low
Mauritania	high	complete	very low	limited	low	low	none	medium	low
Mauritius	low	low	very low	limited	medium	no Data	none	low	low
Mexico	high	complete	very good	very good	medium	low	some	medium	some
Micronesia	low	low	very low	limited	medium	no Data	none	low	low
Mozambique	medium	advanced	some	limited	low	medium	none	medium	some
Myanmar	low	low	good	very good	medium	high	some	medium	large
Namibia	medium	advanced	limited	good	low	low	none	medium	low
Nepal	medium	low	good	very low	low	medium	some	high	some
Nicaragua	medium	complete	some	limited	high	medium	some	medium	large
Niger	medium	advanced	very low	some	low	low	none	medium	low
Nigeria	low	low	very low	limited	medium	low	some	medium	some
Pakistan	low	low	very low	limited	high	low	none	medium	low
Palau	medium	advanced	some	limited	high	no Data	none	low	low
Panama	high	advanced	good	limited	high	high	some	low	large
Papua New Guinea	high	low	some	some	low	high	some	medium	large
Paraguay	medium	advanced	some	very low	low	high	some	medium	some
Peru	medium	advanced	very good	good	low	high	high	medium	some
Philippines	low	low	very low	very good	medium	medium	some	medium	some
Rwanda	medium	advanced	very low	good	low	low	none	medium	large
Saint Lucia	medium	complete	limited	very low	high	high	none	low	low
Saint Vincent and the Grenadines	low	low	very low	very low	high	high	none	low	low
Samoa	medium	complete	some	very low	high	no Data	none	low	low
Sao Tome and Principe	low	low	very low	very low	high	high	none	low	low
Senegal	medium	advanced	very low	good	low	low	none	medium	large
Sierra Leone	low	low	very low	very low	medium	high	none	medium	some
Singapore	low	low	very low	very low	medium	low	none	low	low
Solomon Islands	low	low	very low	very low	medium	high	some	low	low
Somalia	low	low	very low	very low	medium	low	none	medium	low
South Africa	medium	advanced	good	very low	low	low	none	medium	low
Sri Lanka	low	low	good	good	medium	medium	none	low	some
Sudan	low	low	some	limited	low	low	none	medium	some
Suriname	low	low	limited	good	low	high	high	medium	some
Swaziland	low	low	limited	good	medium	low	none	medium	low
Thailand	low	low	good	good	medium	medium	some	medium	large
Timor-Leste	low	low	some	very low	medium	medium	none	low	some

Country	Engage-ment in UNFCCC REDD process	Complete-ness of GHG inventory	Forest area change monitoring capacity	Forest inventory capacity	Remote Sensing technical challenges	Proportion of tree canopy cover > 40%	Amount of intact forest	Importance of fire/ biomass burning	Carbon storage in forest soils
Togo	low	low	very low	very low	medium	low	none	medium	low
Trinidad and Tobago	medium	advanced	good	good	high	high	none	low	low
Uganda	low	low	limited	good	medium	low	some	high	some
Tanzania	medium	advanced	some	very low	low	low	some	high	some
Uruguay	medium	advanced	good	very low	low	low	none	low	some
Vanuatu	medium	low	limited	very low	high	low	none	low	large
Venezuela	low	low	very low	very low	medium	high	high	medium	some
Vietnam	high	advanced	very good	good	low	medium	some	medium	large
Zambia	low	low	limited	limited	low	medium	some	high	some
Zimbabwe	medium	advanced	some	limited	low	low	none	medium	low

Appendix B: Recommendation reports for a selection of 30 countries

These recommendations are presented in alphabetical order and have been derived from the analysis of international and publically available documents and data sources. They are intended to provide guidance and suggestions but should be further discussed and elaborated with the individual countries before they can be used in defining or implementing specific actions.

Bolivia	***Land area: 1,084,380 km² (FRA 2005)*** ***Forest cover: 54.2 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Annual deforestation rate is estimated at 0.5% annually in the period 2000-2005 (FRA 2005). Forest loss is attributed mainly to agricultural activities (extension of agricultural frontier on large scale, slash and burn agriculture on the small scale) and illegal logging. The monitoring of deforestation uses methodology of INPE/Brazil and is focused rather on illegal interventions than on the detection of area changes. The Forests Superintendence implemented a monitoring system in 2005. Hot spot areas of deforestation in Bolivia are known.
Responsible institutions	The Forests Superintendent is responsible for forest monitoring as well as forest inventories. The Superintendence is supported by the Legal Affairs Ministry and the Courts for forest law enforcement; and by the Forestry Directorate, Viceministry of Biodiversity, Forestry and Environment in the field of forestry and forest conservation. The Forests Superintendence is also responsible for the FRA reporting to the FAO. Engagement of Bolivia in the REDD process is high (National Communication to the UNFCCC, several REDD submissions to SBSTA, R-PIN to FCPF), and is designated pilot country in the UN REDD programme.
Available remote sensing data	Bolivia is regularly covered by Landsat and CBERS sensors. However, optical satellite imagery is affected by high cloud coverage (mean annual: 57%), recent cloud-free SPOT data (2006-2008) is only available for about one-quarter of the county area in average and also cloud-free historical SPOT data is only available for one year during the 1990-2005 period. The approach used to detect deforestation in Bolivia is currently based on MODIS data and considered unsuitable to accurately quantify forest area change. To update the national database (since 2005) processing of Landsat and CBERS imagery is conducted by the Noel Kempff National History Museum (MHNKM). Furthermore, ALOS data is explored to complement degradation assessment for dry deciduous forests (optical data suffering from seasonality effects).
Carbon measurements	GHG emissions from the LULUCF sector were estimated for 1990, 1994, 1998 and 2000. These emissions were progressively increasing up to nearly 45 million tonnes of CO_2. Bolivia has 540 permanent plots of biomass that are periodically re-measured. However, until now Bolivia was not able to establish a comprehensive national biomass inventory covering all forest types. This is due to the high diversity of forests in Bolivia with a broad range of biomass. All forest concessions have forest inventories (5-year frequency). Impact of degradation is not monitored operationally but currently investigated using methodology based on Normalized Difference Fractions Index (NDFI).
National recommendations	
Infrastructure	**Institutional framework must be strengthened** including an improved coordination among the various governance and administration agencies on the different levels of decentralized government. **Legal premises should be issued to promote sustainable management, resolve claims of forest ownership and competency**. Poor internet connectivity should be improved to ensure reliable access to required data sources.
Human resources	Expertise in processing and analysis of remote sensing data is available, additional training may become necessary for the launch of a degradation monitoring system. **Improvement of human capacity should mainly focus on the establishment of a national forest and carbon inventory**.
Annual forest area change monitoring	It is suspected that much of **deforestation and forest degradation activities takes place on a rather small scale requiring high resolution remote sensing data** for a reliable detection. Bolivia can improve its forest monitoring strategy by the use of Landsat and CBERS data that will allow a significant better assessment of forest area change. Due to high cloud coverage and pronounced in-country variability, radar data may help to fill data gaps to ensure an annual updated data base when going for a wall-to-wall approach. **Less frequent wall-to-wall coverage complemented by an adequate sampling strategy for annual updates could be a viable alternative**. Capacity building for such a monitoring system is necessary. ASTER data proved to deliver most cost-effective results for the detection of degradation. Semiannual approach is

	recommended to detect forest degradation.
Carbon measurements	**A national forest carbon inventory needs to be established**. Expertise may be transferred from work done with existing permanent sample plots of Bolivia; however, additional human and technical resources will be needed for measurements as well as data analysis and interpretation to implement a consistent country-wide system. Required steps include: - Identification of national key categories - Develop sampling design and national stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Brazil	***Land area: 8.459.420 km² (FRA 2005)*** ***Forest cover: 57,2 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Brazil's forest area change monitoring relies on annual Landsat and CBERS data and provides operational remote sensing monitoring system, providing accurate measurements of annual deforestation in the Amazon region. Much less forest monitoring is taking place outside of the Amazon zone.
Responsible institutions	The PRODES program (Project for Gross Deforestation Assessment in the Brazilian Legal Amazonia) monitors land cover using satellite and other remote sensing data, allowing the annual estimation of gross rates of deforestation. PRODES has developed sophisticated land use change predictive models, and near-realtime deforestation monitoring using coarse resolution (MODIS) imagery is in place. In 2008, TerraAmazon, a product developed by Brazil's National Institute for Space Research (INPE), is available and is used to provide automated, weekly clear-cutting alerts to forest managers under Brazil's Legal Amazon Deforestation Monitoring Program (PRODES). Brazil has submitted views on REDD to the UNFCCC 2005 including a GHG inventory for LULUCF (tier 2). Brazil is engaged in the GOFC-GOLD Amazon and the GOFC-GOLD RedLaTif Regional Network.
Available remote sensing data	Brazil is regularly covered by Landsat TM & CBERS and both data is used within the diverse Brazilian monitoring programmes. MODIS and CBERS-WFI data is used for real-time deforestation/degradation monitoring.
Carbon measurements	A full national forest inventory is available but very old. Since the early 1970s no update has been done at national level. Locally derived allometric biomass equations are available, derived by external consultancy that estimated forest biomass and resulting carbon stock in Brazil. These values have been used for FRA and UNFCCC reporting. Permanent measurement plots exist in the Amazon Region. Carbon stock values have been reported for FRA 2005 using using Tier 2 factors in the FAO FRA 2005 and national values for aboveground biomass. Brazil estimated GHG emissions from forestry in its National Communication to the UNFCCC in 2004. Brazil participates in the NFMA project of the FAO but has not yet completed its NFA.
National recommendations	
Infrastructure	Technical capacity (hard- and software) for image processing and analysis is very good. **For the implementation of a national forest inventory strategy, equipment for in-situ measurements is required.**
Human resources	Human capacity in remote sensing is solid but **adequate personnel numbers and training is necessary to implement a thorough national inventory strategy**.
Annual forest area change monitoring	Brazil has excellent remote sensing capacity. Monitoring of forest area change is well established and several programs (DETER, DEGRAD, DETEX) are targeted to detect forest degradation. **Brazil should provide support to other countries** based on experiences concerning the development and implementation of a comprehensive monitoring strategy and in providing free and pre-processed CBERS adat.
Carbon measurements	Brazil requires the development and implementation of a national forest carbon measurement system. Activities are ongoing and efforts can build upon existing experience from various study sites and participation in the FAO NFMA program. A systematic, consistent inventory approach on the national level generating data adequate for carbon reporting according to IPCC Tier 2 will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Cameroon	***Land area: 465,400 km² (FRA 2005)*** ***Forest cover: 45.6 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	A MINFOF (Ministry of Forestry and Wildlife)/WRI (World Resources Institute) collaboration through their GFW (Global Forest Watch) initiative, is currently the only forest monitoring programme. The GFW project is limited to the monitoring of the PFD (Permanent Forest Domain), the nPFD (non-Permanent Forest Domain) is not monitored although being more susceptible to deforestation and forest degradation. A national forest program is being implemented since 2004. Deforestation rates are estimated at 1% of forest cover loss per year for the period 2000-2005.
Responsible institutions	MINFOF is responsible for the monitoring and inventory of forest areas, for the management of protected areas and the legal framework of forestry. UNFCCC related activities and monitoring of conservation activities are coordinated by MINEP (Ministry of Environment and Nature Protection). For the FRA 2005 reporting to the FAO, the Ministry of Environment and Forestry (MINEF, now split up into MINFOF and MINEP) was in charge. Cameroon is highly engaged in the REDD initiative (UNFCCC National Communication, SBSTA submissions, R-PIN) and participates in the regional GOFC-GOLD network OSFAC (Observatoire Satellital des Forêts d'Afrique Centrale) and (together with other central African countries) in the Central African Forest Commission (COMIFAC).
Available remote sensing data	Several small-scale remote sensing operations have been developed by the FAO and the Observatory for Central African Forests (OFAC). Given the limited availability of good quality satellite imagery ascertained for SPOT and ASTER data, currently DMC (Disaster Monitoring Constellation) images are analyzed, which were acquired in collaboration with GTZ in the framework of a multi-user partnership. Recent Landsat data is not available since the central African region lacks a receiving station.
Carbon measurements	Carbon emission estimations from deforestation and forest degradation provided with Cameroon's national communication to the UNFCCC are not considered reliable. A national inventory is available from 2003/2004, developed with the assistance of FAO. Cameroon received funding in the framework of FAO's National Forest Monitoring and Assessement (NFMA) project. Following Hardcastle et al. (2008) the forest inventory capacity developed in collaboration with FAO arrived at the level of IPCC Tier 2. Furthermore, a REDD pilot project in Cameroon aims to develop a national biomass and GHG emissions inventory for the forestry sector and to establish a national biomass inventory and monitoring system.
National recommendations	
Infrastructure	National institutions are considered unable **to sustain a forest inventory; the collaboration with NGOs is necessary to establish permanent capacity** in this field. Cameroon's internet connectivity is slow and should be improved to ensure a reliable data access. The availability and the capability to process satellite remote sensing data can be enhanced through the **installation of a receiving station and investments in hardware and software** for the implementation of GIS and remote sensing data processing, respectively. Community-based approaches for forest management may help the fight against deforestation and forest degradation and promote sustainability. Communication between various national institutions responsible for REDD must be ascertained, possibly MINEP should control consultations.
Human resources	**Technical competence has to be fostered in the elaboration of GHG inventories** and the use of IPCC approved methodology, the application of remote sensing data and the implementation of GIS.
Annual forest area change monitoring	There is **urgent need for an update of Cameroon's national monitoring** since cartographic information is out of date, does not reflect the current situation of Cameroon's forests and lacks spatial accuracy. Several donor activities and international capacity building support are already ongoing to complete the historical forest monitoring. The utility of remotely sensed satellite imagery for country-wide mapping is partially hampered by the high degree (69%) of mean annual cloud coverage (at least for some part of the country as cloud coverage shows considerable in-country variability). **The establishment of a receiving station for Landsat data for the central African region and the use of radar data are ways to improve the availability of remote sensing data**. A forest definition has to be adopted to support the development of a REDD strategy and guide the requirements of a monitoring system.
Carbon measurements	The formulation and **implementation of a national forest carbon inventory strategy requiring the development of allometric equations, expansion and conversions factors** necessary to calculate forest biomass and carbon was initiated with Cameroon's NFA with support from the FAO. Building on existing capacity small additional effort is needed to achieve Tier 3 (annual re-measuring of a proportion of the permanent sample plots); the additional **incorporation of degradation monitoring** would require considerably more effort.

Central African Republic (CAR)	***Land area: 622.980 km² (FRA 2005)*** ***Forest cover: 36,5 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	CAR has no national forest monitoring programme in place, due to the lack of a national structure capable of gathering mapping information and to pilot forest monitoring. Forest mapping information is mainly produced by international and regional projects (e.g. CARPE, OFAC). Limited capacity is available in country (GIS laboratory at University of Bangui). There is a receiving station installed in Bangui but data is processed and analyzed by the European Research Centre (JRC). Historical deforestation rates of CAR are very low: 0,1 % per year for 2000-2005 (FRA 2005). Recently, the World Resources Institute (WRI) has been commissioned by CAR to complete an interactive atlas of the forests of CAR.
Responsible institutions	Two departments of the Ministry of Water, Forests, Hunting, Fishing and the Environment (MEFCPE) are responsible for the forestry sector: - Department of Forest Inventorying and Management Planning (DIAF) for forest inventories - General Forestry and Water Commission (DGEF) for forest monitoring. CAR is very engaged in the REDD process. It has submitted a National communication to UNFCCC, participated in 5 REDD submissions and has prepared an R-PIN for FCPF. CAR participates in the GOFC-GOLD Regional Network OSFAC.
Available remote sensing data	No Landsat receiving station covers CAR. CBERS data are regularly available for CAR. Availability of cloud free historical SPOT data is very limited. CAR has high average annual cloud coverage (58 % of country area), with high in-country variability and seasonality. In March and April the cloud cover is lowest in the long-term average. Recently, national institutions have acquired satellite imagery for south-west CAR (DMC, ASTER, and ALOS PALSAR).
Carbon measurements	The most complete forest inventory was completed 1991-1994 supported by the World Bank. It was carried out throughout the southwest forest and used the series of aerial photographs produced in 1989. A National estimation of (GHG) was presented in the National Communication for the UNFCCC (using tier 1). Precise estimations of CO2 emissions from deforestation and forest degradation are not available, due to missing of specific data for calculating forest biomass. Several regional inventory data are available for the south-west forest area, as well as precise stratification maps.
National recommendations	
Infrastructure	CAR does not have a dedicated institution to address cartographic topics that can host **a national forest monitoring system and fundamental infrastructure needs to be established**. CAR does not have a satellite image database available to conduct annual monitoring of the forest. Necessary **hardware, as well as GIS and remote sensing image processing software is needed**. Internet speed is relatively low, better internet access needs to be established to improve data access or other data access procedures (i.e. DVD delivery or through regional centres) should be pursued.
Human resources	CAR needs human capacity in terms o trained GIS and remote sensing experts**. Knowledge on GIS and satellite image interpretation needs to be built** to enable for satellite based image processing, forest change analysis, detection of degradation, and ground measurements.
Annual forest area change monitoring	**A national forest monitoring strategy** (including forest definition and national stratification) **needs to be developed**. The high cloud cover probability requires multi-date imagery and suggests the **integration of radar data**. The forest resources of CAR are regularly affected by fire (>40 % of forest area, 2000-2007). It is a very important factor or deforestation and degradation. Hence, **a regular fire monitoring system is recommended**. CAR has high percentage of dry tropical forest. Phenology effects need to be considered in the interpretation and require multi-date data and advanced interpretation skills. Close cooperation to Central Africa Forest Commission (COMIFAC) and Observatory of Central African forests (OFAC) is recommended.
Carbon measurements	Based on existing regional inventories, it is necessary to **install a national systematic and standardized forest inventory system**. Relevant institutions need capacity building for biomass monitoring, carbon accounting and implementing measurement plots. In the frame of preparing its second National Communication, CAR has already received assistance (UNFCCC, GTZ, and France) to develop skills regarding national GHG emission inventories and reporting. This capacity needs to be strengthened. To move toward tier 2, it is needed to: identify key carbon pools, install measurement plots for country specific allometric data, etc.

Colombia	***Land area:1.038.700 km² (FRA 2005)*** ***Forest cover: 58,5 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Columbia has done a forest area change monitoring between the years 1986, 1996 and 2001. This study which was published in 2004 and indicates that of the national land area, 49% or 55'882,000 hectares are forests (natural and plantations), and that of this areas there is a loss of 77,000 hectares/year between 1986 and 1994 and of 101,000 hectares/year for the period between 1994 and 2001. The identification and classification of vegetation cover in different units with is done by using remote sensors (Landsat TM imagery, for the 80s, and 90s decades, and years 2000 to 2003) and the translation of these in vegetation cover maps and current use maps, for years 1986, 1994 and 2001, over which trend analysis are done. It is important to specify that due to the lack of consecutive satellite imagery (due to cloud cover or missing images for specific periods), it was necessary to implement an interpolation of the analyzed areas to be able to determine the mosaic base year. By analyzing protected areas4, and the change in forest cover in these areas until 2005 at a semi-detailed level, it was estimated that the deforestation rate is 2,300 ha/year.
Responsible institutions	In Columbia the Hydrology, Meteorology and Environmental Studies Institute (IDEAM) and SINA (National Environmental Information System) Research Institutes are responsible for national forest monitoring and forest inventories. The Ministry of Environment, Housing, and Territorial Development (MEHTD) is the central leading entity that defines natural resource policy, including forests protection and use. A REDD monitoring system would require a greater effort to collect data and information at the field level. Colombia has submitted a National Communication to UNFCCC (including a GHG inventory for LULUCF, tier 1) and prepared an R-PIN for the FCPF.
Available remote sensing data	Columbia is covered by CBERS and Landsat TM . Recently, Columbia used full country coverage of historical Landsat TM data (1986, 1994 and 2001).
Carbon measurements	The areas of the country that are affected by deforestation are known and described. The results of the consolidated CO2 emissions and absorptions and emissions of non CO2 gases from activities in the LULUCF sector is reported in the RPIN. SIMSI (United Nations Office for Drugs and Crime satellite imagery analysis system) has estimated that the burning of natural forests due to illicit crops destroys 280 tones of biomass per hectare, which means 152 million tones of biomass that have turned into ashes, CO2 and sediments. Carbon stock values have been reported for FRA 2005 using Tier 1 default values and national values for aboveground biomass.
National recommendations	
Infrastructure	**Technical capacity (hard- and software) is required for image processing and analysis**. Internet connectivity is relatively slow, better internet access needs to be established to develop data access for annual coverage. Improving technology used for forest monitoring, such as ALOS imagery that also surpasses barriers of imagery interpretation due to clouds. **Technical capacity should be built in local communities to promote sustainable forest management** using appropriate technologies and implementing good practice guidance.
Human resources	The required monitoring efforts are currently hampered by lacking financial, technical and institutional support. Hence, basic **training of specialized personnel is necessary**. A REDD monitoring system requires greater efforts and capacities to collect in-situ data.
Annual forest area change monitoring	**A national monitoring system should be developed and implemented**, which can be based on Landsat, SPOT and CBERS as primary source of remote sensing data. Additional radar data should be used to fill data gaps. Regarding this issue, partnerships to bordering countries should be established.
Carbon measurements	**A national forest carbon inventory needs to be established** and requires the necessary technical and human resources fieldwork, measurements as well as the data interpretation and analysis. Steps for moving to Tier 2: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification - Expertise to estimate historical emissions from deforestation and degradation

Congo	***Land area: 341,500 km² (FRA 2005)*** ***Forest cover: 65.8 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Low rates deforestation and degradation rates are observed for the country; the FRA 2005 report estimates the rate of forest area loss at 0.1% annually for the period 2000-2005. In the framework of CARPE (Central African Regional Program for the Environment) deforestation and forest degradation analysis for the Congo Basin was done. JRC and UCL estimated forest degradation at a very low degree as well (0.01% annually for the period 1990-2000). Both processes, deforestation and forest degradation, are mainly focused in the south of Congo. The country is participating in the NFMA project of the FAO, the assessment is currently still in progress. A programme of monitoring forest exploitation and control enforcement of forest law was developed by CNIAF (Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques) and is implemented since 2007. Forest monitoring for the whole Congo basin is managed by OFAC (Observatoire des Forêts d'Afrique Centrale) within the FORAF (Forests of Africa) project to assess the periods 1990-2000 and 2000-2005.
Responsible institutions	The Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques (CNIAF) and the Directeur Général de l'Economie Forestière are responsible for forest monitoring and inventories in Congo. The Ministère de l'Economie Forestière and the Ministère du Tourisme et de l'Environnement both are in charge of forestry, forest conservation and forest law enforcement. FRA reporting to the FAO is done by CNIAF. Congo shows strong engagement in the REDD process (National Communication to the UNFCCC, participation in several joint submissions to SBSTA, R-PIN to FCPF). Congo participates in the regional GOFC-GOLD network OSFAC (Observatoire Satellital des Forêts d'Afrique Centrale) and is engaged in the Congo Basin Forest Partnership. (CBFP) and the Commission des Forêts d'Afrique Centrale (COMIFAC) initiative.
Available remote sensing data	Recent Landsat 5 data are available only for a small proportion of Congo. Optical remote sensing data is severely affected by a very high degree of cloud coverage (mean annual of 81%), cloud-free SPOT imagery is not available at reasonable amount, neither from historical nor from recent records. The FORAF project analyzes historical Landsat data to assess the dynamics of deforestation (and reforestation) as well as forest degradation (and regeneration). Landsat data was used for mapping of landcover and different types of forests in 2003/2004; the results were used for FAO FRA 2005 report. Earlier historical information that might help understanding these dynamics is available as aerial photographs from the 1960s.
Carbon measurements	Existing data originates from several types of inventories including historical records (1970s) for paper pulp industry and more recent data collected within forest management planning process (covering 4.5 million ha in northern Congo) and harvesting inventories. There is no consistent national data base but Congo is participating in FAO's NFMA project where work is still in progress. The inventory data used for FRA 2005 is based on a commercial focus, beginning at minimum DBH of 40 cm at best, what is considered inadequate for carbon estimation. Minimum DBH is planned to be reduced to 20 cm for the next assessment. Carbon stocks in the FRA 2005 report to the FAO were estimated using Tier 1 default emission factors. A study to estimate biomass and carbon from high-resolution satellite imagery funded by ITTO, carried out by Winrock International, CNIAF, WCS (Wildlife Conservation Society) was planned to be finished in April 2009. No reliable estimates of GHG emissions from deforestation and degradation exist; GHG estimates were not included in Congo's National Communication to the UNFCCC in 2001, a first assessment of GHG emissions from the LULUCF sector was provided with Congo's second National Communication to the UNFCCC and mentions negative GHG emissions, i.e. a sink.
National recommendations	
Infrastructure	**Congo is in need of technical equipment** (hardware, software) **for data processing** required for monitoring and inventory purposes. **The country would benefit from a central African receiving station for Landsat data**. There is poor Internet connectivity for Congo, improvements are recommended to ensure proper data access or alternative approaches should be pursued (i.e. DVD delivery or through regional centres).
Human resources	The available capacity in staff with **technical expertise** to conduct IPCC-compliant carbon inventory fieldwork is limited **has to be enhanced to achieve Tier 2 reporting** on a national basis; however, it can be assumed that capacity building is underway with Congo participating in path-breaking collaborations like NFMA (FAO) and OFAC. Experience with Landsat data exists in Congo and can be used and enlarged for the work with other Landsat-type data (e.g. CBERS). Additional **capacity building is recommended for the application of radar data**.
Annual forest area change	Limited availability of high-resolution satellite imagery does not allow annual or even bi-annual monitoring. **A combination of historical Landsat, SPOT and Radar data should applied given the high degree of cloud**

monitoring	**coverage**. A central African receiving station should improve data availability. Especially monitoring of forest degradation will benefit from higher resolution (temporal and spatial) imagery.
Carbon measurements	**A national forest carbon inventory needs to be established**. Therefore, the implementation of human and technical resources is needed for fieldwork, measurements as well as data analysis and interpretation. Tier 2 reporting will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools Future studies should incorporate the assessment of soil organic carbon. Lack of data and high costs to implement systematic field sampling prevent advancements regarding this important carbon pool.

Costa Rica	***Land area: 51.060 km² (FRA 2005)*** ***Forest cover: 46,8 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Costa Rica does its forest inventory at local sites using remote sensing data. Landsat images are being used since 1997. Only in areas under Payment for Environmental Service Program preventive monitoring is regularly carried out.
Responsible institutions	SINAC (The National System of Conservation Areas) has the responsibilities for the implementation of national policies related to the biodiversity and is also responsible for conduction the country forest inventory. FONAFIFP (The National Forestry Financing Fund) is responsible for monitoring forest cover by using satellite images combined with field verification. FUNDECOR (Fundación para el Desarrolio de la Cordillera Volcánica Central) elaborates ancillary period studies in the conservation area of the central volcanic range. Engagement in REDD communication is high and a R-PIN for the FCPF is prepared.
Available remote sensing data	Availability of optical satellite imagery is sometimes affected by high cloud coverage (mean annual 80,08%). For 2006-2008 annual cloud-free Spot images are available for about the half of the country area.
Carbon measurements	Estimates of GHG are available and based on projections of numbers from a carbon compensation project for pilot areas.
National recommendations	
Infrastructure	The governmental institutions already host some infrastructure useful for regular forest monitoring purposes. **Existing technical capacity (hard- and software) for image processing and analysis should be assessed and expanded to increase detail and accuracy for measurements and monitoring.**
Human resources	**Expertise in processing and analysis of remote sensing data is available, additional training may become necessary for the launch of a degradation monitoring system. Improvement of human capacity should mainly focus on the establishment of a national forest and carbon inventory.** Therefore, human capacity is needed to undertake regular forest monitoring i.e. more technical staff and technical training for processing and analyzing of remote sensing data to assess forest area change (optical and radar).
Annual forest area change monitoring	**A national monitoring system for degradation and cover quantification is in planning and this process should be fostered and supported; including the monitoring of forest regrowth.** Regular coverage or higher-resolution resolution data will be needed to assess degradation.
Carbon measurements	**A national forest carbon inventory needs to be established**. A permanent forest inventory is proposed for the country, which would make it possible to determine the forest (re-)growth, increases in carbon stocks and structure and composition. Expertise may be transferred from work done with existing permanent sample plots of Costa Rica; however, additional human and technical resources will be needed for measurements as well as data analysis and interpretation to implement a consistent country-wide system. Required steps include: - Identification of national carbon stock key categories - Develop sampling design and national stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Democratic Republic of Congo	***Land area: 2.267.050 km² (FRA 2005)*** ***Forest cover: 58,9 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Several land cover products are available for DR Congo, produced by or with support from external institutions or consultants (e.g. CNIE, UCL), including a LCCS based LC Map. With support from WWF deforestation analyses were done in several forest reserves of DR Congo. In general, deforestation in DR Congo is relatively low, the annual deforestation rate from (2000-2005) is 0,2 % (FRA2005). Currently, several international forest and deforestation mapping activities are ongoing addressing the entire Congo Basin i.e. Observatory for the Forests of Central Africa (OFAC, JRC), Central African Regional Program for the Environment (CARPE, USAID), in close cooperation with the national authorities in the region.
Responsible institutions	The Department for Permanent Service for Forest Inventory and Management (SPIAF) under the Ministry of Environment, Nature Conservation and Tourism (MECNT) is responsible for forest monitoring and inventories and for FRA reporting. DR Congo is very engaged in the REDD process. It has submitted a National Communication to UNFCCC (including a GHG inventory for LULCF, tier 1), participated in five REDD submissions and prepared an R-PIN for FCPF. DR Congo participates in the GOFC-GOLD Regional Networks: SAFNet and OSFAC and is designated pilot country in the UN REDD programme.
Available remote sensing data	Only 70 % of the country area can be covered by current Landsat receiving stations. There is no information available on cloud free SPOT data. The average cloud cover probability is very high (70 %), with high in-country variability and seasonality (most suitable months are April/March).
Carbon measurements	Inventories from the 70's and 80's are available done by SPIAF (with Canadian support) but not suitable for carbon estimates (focus on harvestable wood). Further harvesting inventories have been done recently at regional level. No national biomass measurements are available. Carbon estimates for three carbon pools (ABG, BGB, and dead wood) have been reported in FRA2005 using Tier 1 default values.
National recommendations	
Infrastructure	The **construction and maintenance of a satellite imagery receiving station in Central Africa** is suggested. Building upon SPIAF equipped laboratory and trained technicians (from partners), **basic national monitoring capacities need to be established**. **DR Congo would benefit from a sustained regional cooperation and coordination on forest monitoring.**
Human resources	SPIAF has level staff in remote sensing and cartography, but further **expertise is needed to monitor fine-scale forest changes and forest degradation**, **and for in-situ measurements of carbon stocks and changes.**
Annual forest area change monitoring	**Landsat TM and SPOT data should be used primarily in the forest monitoring** but cloud coverage is an issue in the DR Congo. **Radar data provide an additional option to achieve full coverage, however are not fully available yet (interaction with JAXA needed)**. About one third of the forests are dry or deciduous forests. Phenological effects need to be considered for forest monitoring. The forests of DR Congo are regularly affected by fire (approx. 18 % of forest cover in long-term average). **Establishing a fire monitoring is therefore recommended**.
Carbon measurements	**A national forest carbon inventory needs to be established** and requires the necessary technical and human resources field work, measurements as well as the data interpretation and analysis. Steps for moving to Tier 2: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification

Ecuador	***Land area: 276,840 km² (FRA 2005)*** ***Forest cover: 39.2 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	A forest map covering the continental mainland of Ecuador was produced by CLIRSEN (Centro de Levantamiento Integrado de Recursos Naturales por Sensores Remotos – Centre for Integrated Surveys of Natural Resources through Remote Sensors) for the reference period 1997-2000. Other roughly reliable information does not exist (neither recent nor historical). Deforestation in Ecuador is specified at 1.7% annually averaged for the 2000-2005 period. Ecuador has one of the highest deforestation rates of Latin America. Major drivers are agricultural expansion and illegal logging. Ecuador plans to participate in the NFMA project of the FAO and formulated a NFA, which is, however, currently not yet implemented.
Responsible institutions	The Ministry of Environment is responsible for the coordination of forest inventories and forest monitoring in Ecuador. FRA 2005 reporting to the FAO was carried out under responsibility of the Dirección Nacional Forestal which is part of the Ministry of Environment. Ecuador showed so far decent engagement in the REDD process (providing submissions to SBSTA and National Communication to UNFCCC but no R-PIN).
Available remote sensing data	Landsat can provide data for only 71% of the country area, since the country is not fully covered by receiving stations. Availablity of CBERS data should be checked; unfortunately, optical data has limited utility for Ecuador due to persistent cloud cover (mean annual of 86%). Consequently, high quality (cloud-free) SPOT imagery is available neither at roughly country-wide coverage. CLIRSEN used remote sensing data to produce the aforementioned forest map of Ecuador and possesses considerable capacity of remote sensing data processing, including radar data.
Carbon measurements	Following Ecuador's National Communication to the UNFCCC, the LULUCF sector is responsible for the highest proportion of Ecuador's total GHG emission. Ecuador strives toward a participation in the NFMA project of the FAO and already formulated but not yet implemented a NFA. Until now, no recent nor historic values are available; consequently no values of growing stock, biomass and carbon were submitted within Ecuador's FRA 2005 report.
National recommendations	
Infrastructure	**Hard- and software for data processing required** to monitor forest cover change and forest degradation by the means of remote sensing and GIS will be premises to implement a solid national monitoring and inventory program. Building on existing experience from CLIRSEN, Ecuador may be able to assess the required effort to achieve this goal. **Equipment for field measurements will be required to implement a national forest inventory**. Data accessibility would benefit from the improvement of Ecuador's moderately fast internet connectivity.
Human resources	The implementation of a national forest carbon inventory and the establishment of a REDD-compliant monitoring system will require substantial effort regarding the training of qualified personnel. Especially regarding **capacity building in the domain of forest inventory**, carbon stock assessment and GHG/carbon emission estimation according IPCC guidelines, Ecuador will rely on support from FAO, NGOs or other external consultancy.
Annual forest area change monitoring	An annual monitoring system for Ecuador will require the **incorporation of radar data** to complement available optical imagery. (Although steep terrain in considerable parts of the country (13%) may further complicate the use of remotely sensed data.) **A strategy for regular national monitoring of forest cover and forest degradation must be developed**.
Carbon measurements	**A national forest carbon inventory needs to be established** and requires the implementation of adequate human and technical resources for fieldwork and measurements as well as data analysis and interpretation. Tier 2 reporting will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Gabon	***Land area: 257.670 km² (FRA 2005)*** ***Forest cover: 84,5 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Gabon does not currently have a map of its forest cover or land use change. The country appears to have no in-house remote sensing capacity. No FRA2005 report was submitted by the country. External analysis reveals a very low historical deforestation and degradation rate of 0,12 % for 1990-2000 (OFAC).
Responsible institutions	The Direction for Forest Surveys, Management and Regeneration (DIARF) is responsible for forest monitoring in Gabon. In 1995, a GIS unit was established to manage forest information. Gabon is very engaged in the REDD process. It has submitted an NC to UNFCCC, participated in five REDD submissions, and has prepared a R-PIN for the FCPF. Gabon is engaged in the Regional Network OSFAC and participates in Central African Forest Commission (COMIFAC).
Available remote sensing data	Gabon is regularly covered by CBERS data. The country is not covered by current Landsat TM receiving stations. Landsat 5 data will therefore not be available for future monitoring. The country experiences strong cloud coverage. The average cloud cover probability is 88 %.
Carbon measurements	The inventory capacity is very limited. There is one inventory available done by FAO (1994). Gabon does not have data on biomass specific to its own environment. Carbon estimations were provided in the first national communication to UNFCCC, based on forest data collected in the FAO inventory with additional default factors from the IPCC (tier 1). A second GHG inventory is currently in preparation, supported by UNDP.
National recommendations	
Infrastructure	The **responsible institutions need reinforcement of technical tools**, i.e. computer equipment as well as GIS and remote sensing software. Internet speed is relatively low, better internet access needs to be established to improve data access. Gabon is not covered by a Landsat 5/CBERS receiving station at the local nor regional level to improve image quantity and quality. **A satellite receiving station within the region** is needed and already in discussion through COMIFAC with various partners (e.g. France) and **would help to solve the problem with a lack of remote sensing data access**.
Human resources	The responsible institution has a crucial **need for GIS and remote sensing capacity-building**. This includes strengthening competencies on processing GIS information and remote-sensing data for forest cover mapping and forest change analysis.
Annual forest area change monitoring	Gabon needs fundamental capacities to **implement a remote-sensing monitoring system** of forest areas at the national level including the develop of a monitoring strategy, and a national database on forests. Historical Landsat and current SPOT should be the primary source of data. The **integration of radar data is recommended**, given the high cloud coverage in the region. The forests of Gabon are regularly affected by fires. **A fire monitoring system is recommended**.
Carbon measurements	**Gabon needs a continuous, systematic and standardized national forest inventory system**, including a network of permanent plots. Technical capacity and trained personnel to monitor GHG emissions from the forest sector is needed. An annual or regular national forest survey is needed that will allow a comparison between satellite images and field data in order to estimate of changes in forest cover, and losses and increases in carbon stocks.

Ghana	***Land area: 227.540 km² (FRA 2005)*** ***Forest cover: 24,2 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Ghana has a high deforestation rate of 1,9 % per year between 2000-2005 (FRA2005). There is no regular monitoring system in place. For FRA reporting apparently no remote sensing data was used. Recently, the CERSGIS (see below) has started to process time series of satellite into forest image maps for the Ghana Forestry Commission to assess trends of changes in forest cover. For 2000/01 a satellite based national land cover map is available.
Responsible institutions	In Ghana two institutions are involved in forest monitoring: - The Resource Management Support Centre (RMSC) of the Ghana Forestry Commission (FC) holds a Resource Information System (RIS) and is responsible for forest monitoring, mapping, and forest inventories. - The Centre for Remote Sensing and Geographic Information Systems (CERSGIS) of University of Ghana stores geographic location and descriptive attributes of the managed forests. It provides services to the FC with respect to satellite maps of all forest areas as well as remotely sensed data. Ghana is very engaged in the REDD process (NC to UNFCCC, Participation in four REDD submissions, Preparation of R-PIN). Ghana participates in the West African Regional Network (WARN).
Available remote sensing data	Ghana is regularly covered by CBERS. It is not covered by current Landsat TM receiving stations. Therefore, no Landsat 5 imagery is available for future monitoring. Ghana has a high average annual cloud cover probability (67 %) with high in-country variability and seasonality. In July and August least cloud coverage is observed. In the archives some cloud free SPOT data is available. For 2 years between 1990 and 2005 more than 80 % cloud free images are available. The CERSGIS has satellite data available.
Carbon measurements	No biomass measurements are available for Ghana. Several regional forest inventory data exists on growing stock. Carbon estimates are reported for three carbon pools (ABG, BGB, and dead wood) using tier 1 and reported a GHG inventory in its NC to UNFCCC. A second GHG inventory is in preparation, supported by UNDP.
National recommendations	
Infrastructure	Internet speed is relatively low, better internet access needs to be established to improve data access. **Building upon the existing equipment available in CERSGIS, additional hard- and updated software may be needed to ensure a regular monitoring system**.
Human resources	Technical expertise is needed to monitor forest degradation and carbon stock changes from remote sensing data (optical, radar). Furthermore, technical capacity is needed to assess and verify remotely sensed data products, and for ground measurements.
Annual forest area change monitoring	Historical Landsat data and some SPOT data are available and should form the basis for the **establishment of a regular forest area change monitoring system**. Given the high cloud coverage, additional radar data may be needed to achieve national coverage. Fire is an important factor for deforestation and degradation. The establishment of **a fire monitoring system is recommended**. Ghana has to **address** its **lack of credible remotely sensed data and forest inventory data** to monitor changes in forest and the corresponding carbon stock changes. Data about the state of the forest, trends, and its multiple uses and functions are inadequate and need to be revised to comply with REDD demands.
Carbon measurements	Little inventory capacity exists from past regional forest inventories. Building upon this capacity, there is the need to **install a frequent national forest inventory system** to develop national baselines and to monitor carbon stock changes. This includes the development of a national forest stratification, the implementation of permanent measurement plots. **Technical capacity and expertise is needed for the field measurements and the estimation of forest carbon stock changes**.

Guyana	***Land area: 196.850 km² (FRA 2005)*** ***Forest cover: 76,7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	In Guyana, monitoring of forest cover and inventories are done locally, only in relation to harvesting activities. Until now no satellite data has been applied for this purpose. Guyana currently plans to complete a baseline time series of deforestation and degradation together with Conservation International and the Netherlands. The intention is to implement a time series that is monitored every 3-5 years. In cooperation with CI the built up and the analysis of a Landsat/CBERS time series to assess forest cover change has started. The partners from the Netherlands (Wageningen University, SARvision) started to acquire and analyze SAR data (ALOS). Historical deforestation rate is relatively low.
Responsible institutions	Guyana Forestry Commission (GFC) is responsible for planning, management and monitoring the forestry sector and is preparing the FRA reports. Guyana has submitted a National Communication to UNFCCC (including a GHG inventory for LULUCF, tier 1) and prepared an R-PIN for the FCPF. Guyana is engaged in the GOFC-GOLD Amazon Regional Network.
Available remote sensing data	Guyana is regularly covered by Landsat TM & CBERS. The GFC has aerial photos from the 1950s available for the entire Guyana. Recently, GFC has acquired full country coverage of historical Landsat and CBERS data (1990, 2000 and 2005). The country experiences persistent cloud coverage. In the long-term yearly average, more than 80 % of the country is covered by clouds, whereas there is low seasonality. Availability of cloud free SPOT data in the archive is very limited.
Carbon measurements	A national forest inventory is available but very old. Since 1950 no update has been done at national level. A regional forest inventory dates back to 1970; further more recent inventories are available, all focusing on commercial growing stock. Locally derived allometric biomass equations are available, derived by an external research that has estimated of forest biomass and resulting carbon stock in Guyana. These values have been used for FRA and UNFCCC reporting. Permanent measurement plots exist in two areas. In the Iwokrama Reserve, carbon fluxes measurements have been installed. Carbon stock values have been reported for FRA 2005 using Tier 1 default values and national values for aboveground biomass.
National recommendations	
Infrastructure	**More technical capacity (hard- and software) is required for image processing and analysis**. Internet connectivity is relatively slow, better internet access needs to be established to improve data access or data access provided. **Assess whether internet speed is suitable to obtain annual national coverage with remote sensing.**
Human resources	**Basic institutional capacities, staff number and technical skills to implement forest monitoring in Guyana need to be established**. Human capacity is needed to undertake regular forest monitoring i.e. more technical staff and technical training for processing and analyzing of remote sensing data to assess forest area change (optical and radar). A related plan has been developed and submitted to FCPF and partners are already identified.
Annual forest area change monitoring	**Foster the starting national planning process for a national monitoring system use existing data sources to start implementation**. Landsat/CBERS should be the primary source of remote sensing data. Additional radar data should be used to fill data gaps. Regarding this issue, a partnership to Netherlands has been established already.

Carbon measurements	**A national forest carbon inventory needs to be established and requires the necessary technical and human resources** field work, measurements as well as the data interpretation and analysis. Steps for moving to Tier 2:
	- Identification of national carbon stock key categories
	- Develop country specific sampling design and stratification
	- Implement field sample plots to derive the following parameters:
	  o Allometric data (for biomass conversion and expansion)
	  o Carbon fraction values considering country-specific stratification
	- Expertise to estimate historical emissions from deforestation and degradation

India	***Land area: 2.973.190 km² (FRA 2005)*** ***Forest cover: 22,8 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	In India the Forest Survey of India (FSI) produces a State Forest Report (SFR) every 2 or 3 years. For SFR India used remote sensing data since 1987. The SFRs for 2001 and 2003 show that India's forests have stabilized and are now increasing in extent. The accuracy of the SFRs has been specified and improved over time. 200 forest types were classified and canopy density could be estimated in three different classes. Usually the SFR doesn't contain information on growing stock, except for 1984 and 1994, but in next SFR this data will be included again.
Responsible institutions	The major responsibility for planning, management and monitoring the forestry sector has the FSI, an organization under the Ministry of Environment & Forests (Government of India) FSI is preparing the FRA reports. India has submitted a National Communication to UNFCCC (including a GHG inventory for LULUCF, tier 2). Forest cover maps of the country, the States and Union Territories are prepared by FSI and used for carrying out several spatial studies, such as monitoring changes in forest cover, areas under shifting cultivation, assessment of forest density, status of wildlife habitats, forest fragmentation, forest fire affected areas, etc.
Available remote sensing data	In 1982 the National Remote Sensing Agency (NRSA) demonstrated that the space borne satellite data could conveniently do mapping of actual forest cover. FSI used Landsat MSS imagery pertaining to the period 1981-83 for the first assessment of forest cover. For the second cycle of forest cover assessment (1985-1987) Landsat TM imagery was used. Since 1995 India uses their own remote sensing satellite IRS. By now automatically classification process models were used to estimate forest cover and forest cover change. In the long-term yearly average, about 50 % of the country is covered by clouds, whereas there is medium seasonality.
Carbon measurements	Carbon stocks were estimated using Tier 2 factors, but India didn't include GPG emissions from forestry in its National Communication to the UNFCCC in 2004. Established Carbon Models predict that forest carbon stocks will increase from 8,79 GtC in 2005 to 9,75 GtC in 2030. In India is a very good national capacity for forest inventory. There is an existing framework to include measurements of Tier 3 factors for biomass and carbon conversions.
National recommendations	
Infrastructure	Technical capacity (hard- and software) for image processing and analysis is available.
Human resources	The institutional capacities, staff number and technical skills to implement forest monitoring in India is very good. **India could help in international and bi-lateral capacity development**, i.e. taking more responsibility as regional entity for providing data and technical training.
Annual forest area change monitoring	A national monitoring system for land use, land cover and economic modeling already exists in India. Landsat/CBERS could be an ancillary data source of remote sensing data beside IRS imagery. **India has no noteworthy limitations regarding its forest monitoring capacity and may provide support to less progressed countries.**
Carbon measurements	**The national forest carbon inventory** is very good and **requires little more technical and human resources concerning field work, carbon measurements as well as data interpretation and analysis for moving to Tier 3** depending on what path the country chooses to participate in REDD, i.e. monitoring the carbon stock impacts of sustainable forest management and increasing forest carbon stocks.

Indonesia	***Land area: 1.811.570 km² (FRA 2005)*** ***Forest cover: 48,8 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	The control of forest and protected areas in Indonesia is generally weak despite large personnel numbers and good education and training. Forest inventory statistics were based on a national forest inventory carried out between 1990-1994 with regional updates applied in 1996-2000. Remote Sensing capacity in Indonesia is high because land cover maps and deforestation measurements were done by using Landsat imagery. For covering total land area about 350 Landsat scenes are required. Integration between central institutions (such as a national forest inventory) and regional capacity is lacking and needs improvement.
Responsible institutions	The Ministry of Forestry (MoF) of Indonesia is responsible for planning, management and monitoring the forestry sector and relatively advanced in using remote sensing capabilities. Political restructuring has led to constraints of the former monitoring infrastructure. Conflicts among stakeholders have multiplied to due weak governance, unclear tenure and contradictory laws. The Indonesian Natural Resources Accounting and Environment Society (MASLI) contracted GMES (Global Monitoring for Environment and Security) to carry out GHG inventories for five pilot areas. Indonesia has submitted a R-PIN for the FCPF and is also is engaged in the GOFC-GOLD SEARRIN Regional Network, and is designated pilot country in the UN REDD programme.
Available remote sensing data	Indonesia is regularly covered by Landsat TM & CBERS. For monitoring land cover/forest cover and degradation satellite imagery, basically Landsat TM is used. The country experiences persistent cloud coverage. In the long-term yearly average, 84,55 % of the country is covered by clouds.
Carbon measurements	Carbon stocks were estimated using Tier 1 default factors in the FAO FRA 2005. Indonesia did not report GHG emissions from forestry in their national Communication to UNFCCC in 1999. Permanent measurement plot exists, but there is some inventory capacity. GMES carries out GHG inventories for five pilot areas. Inventories on national level are not available; NGOs implemented several project-based initiatives. There is a lack of technical capacity throughout the forestry sector.
National recommendations	
Infrastructure	Technical capacity does exist within Indonesia, including serviceable hardware and software, but **institutional structures must be improved** to efficiently coordinate the use of such resources, both top down (using technical capacity to inform decision making) and bottom up (coordinating reporting of local data to a national information system). Premises are the establishment of a solid legal framework controlling land tenure and responsibilities among government agencies as well as he strengthening of the weak Indonesian governance.
Human resources	The institutional, policy and legislative situation is complex, in a state of flux and still not fully resolved. Although there are a suitable number of trained experts, the **institutional capacities, staff number and technical skills to implement a coordinated national forest monitoring in Indonesia require improvement**. Human capacity development and institutional re-organization is needed to undertake regular forest monitoring. Capacity building towards implementing efficient monitoring strategies and sustainable management is required especially at district level where most decisions concerning forestry are made.
Annual forest area change monitoring	**Indonesia's monitoring infrastructure** suffered from political change and **needs to be strengthened**. Indonesia should make more effort to **raise the required capacity in collaboration with NGOs** as soon as its institutional structure is capable and willing to coordinate this. The implementation of a national monitoring system should consider the application of radar data, in particular if the annual coverage to implement a REDD approved strategy requiring frequent updates for efficient forest monitoring (incl. detection of forest degradation, illegal logging). In addition, the integration of **a fire monitoring system is recommended**.
Carbon measurements	Up to date **forest inventory** data does not exist in Indonesia; **capacity has to be developed** and should build upon the existing network of permanent sample plots and to make use of existing experiences from the project-level, where proven methodology can be transferred and used for scaling up to national level. Occurrence of peat forests in Indonesia characterized by large storage of carbon supports the explicit recommendation to **include forest carbon stock assessment in the national monitoring strategy**. Considerable resources will be necessary to implement a forest inventory strategy on a national basis sustained by adequate technical and human resources. Tier 2 carbon reporting will require the following steps: Identification of national carbon stock key categories; develop country specific sampling design and stratification; and implement field sample plots to derive the following parameters: allometric data for biomass conversion and expansion, carbon fraction values considering country-specific stratification, disturbance matrices tracking transfers between carbon pools

Kenya	***Land area: 569.540 km² (FRA 2005)*** ***Forest cover: 6,2 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	There are several individual activities in forest mapping in the broad sense but they lack coordination for a sustained national effort. Examples include WWF with forest mapping and assessment in the coastal region, UNEP-KFS with time series data on major forest blocks State forests inventories (from 1960s to date), District land use maps (1978) and DRSRS with Vegetation maps.
Responsible institutions	The Kenya Forest Service (KFS) is in charge of forest inventory and monitoring in Kenya. The organization has a forest inventory and GIS Department carrying out natural and plantation forest inventories, biodiversity and socio-economic surveys. The Department of Resource Survey & Remote sensing (DRSRS) is a government agency for natural resource surveys, remote sensing, aerial surveys, vegetation mapping and database development. The Kenya Wildlife Service (KWS) is the government lead agency in charge of protected areas and therefore has capacity on inventory and monitoring in protected areas, with a focus on habitat change and wildlife monitoring. The Kenya Forestry Research Institute (KEFRI) is supporting KFS on forest growth monitoring. Kenya prepared a R-PIN for the FCPF in 2008.
Available remote sensing data	Landsat and CBERS imagery covers only a small part of Kenya. Aerial photographs are available nationwide from 1999, 2001, 2003 but not from subsequent years. In the long-term annual average, 50% of the country is covered by clouds; there is, however, a pronounced in-country variability. Whereas more recent, cloud-free SPOT data is available for the major parts of Kenya.
Carbon measurements	Forest inventory data in Kenya is limited, growing stock estimates reported within the FRA 2005 report are of unknown reliability. Biomass and carbon stocks for FRA 2005 were estimated using IPCC default values (Tier 1). Some inventories for individual areas and ecosystems of Kenya were conducted but are not based on a consistent, systematic strategy. Although, indicative values are noted, data quality and availability is not sufficient to reliably quantify GHG emissions from deforestation and forest degradation. Improvements are probably on the way as Kenya implemented a NFA (still in progress) collaborating with FAO's NFMA programme.
National recommendations	
Infrastructure	**Technical capacity (hard- and software) is required for regular image processing and analysis**. There is a lack of management information system to capture information required for REDD and climate change. Additionally a lack of standards, methods, procedures and guidelines for natural resources data and information collection, management and dissemination guidelines is present. Internet connectivity is fast and access to data can be provided. Institutional challenges are diverse – **coordination of responsible authorities is necessary to enable efficient data collection and management**, the participation among the various stakeholders in the forestry sector should be increased e.g. to promote sustainable management, the legal framework and law enforcement need to be strengthened.
Human resources	Additional **human capacity is needed to undertake regular forest and land monitoring** i.e. more technical staff and technical training for processing and analyzing of remote sensing data to assess forest area change. Moreover, **capacity building is necessary for biomass and carbon stock monitoring and to implement strategies of sustainable resource management**.
Annual forest area change monitoring	**A coordinated national monitoring system has to be established**. Kenya can improve its forest and land monitoring strategy by using SPOT and other satellite data. **The establishment of a satellite receiving station** providing access to Landsat, CBERS and other data for the region **may be important to establish an effective monitoring framework**. Parts of Kenya are affected by persistent cloud cover, data availability of the respective areas can benefit from radar data, which may help to fill data gaps ensuring systematic monitoring on an annual basis.
Carbon measurements	**A national forest carbon inventory needs to be established** and requires the necessary technical and human resources concerning fieldwork, measurements as well as data interpretation and analysis. Since Kenya has small amount of forests remaining, the permanent carbon measurements should include the growth and carbon sequestration of forests.

Laos	***Land area: 230,800 km² (FRA 2005)*** ***Forest cover: 69.9 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Forest cover (and land use) was assessed three times in a 10-year interval 1982, 1992 and 2002. Deforestation was observed throughout the country, mainly due to agricultural/agro-forestal expansion. Mean annual forest area loss was estimated at 0.5% within the 2000-2005 period by FRA 2005 report for Laos. Forest degradation is a serious issue in Laos; a decline of large forest areas (> 1000 ha) and dense forest was observed whereas the proportion of small forest fragments (< 10 ha) increased substantially. In many areas of Laos it is estimated that forest degradation is as alarming as deforestation.
Responsible institutions	The Department of Forestry (DOF) part of the Ministry of Agriculture and Forestry (MAF) is responsible for forest inventories and monitoring. Laos' REDD engagement is rated high (National Communication to UNFCCC, R-PIN submitted to FCPF) and the country participates in the Southeast Asia Regional Research and Information Network (SEARRIN).
Available remote sensing data	Laos is regularly covered by Landsat and CBERS, however, cloud coverage (mean annual 65%) limits data quality. Apparently, there is only very limited in-country expertise concerning the application of remote sensing techniques, any kind of national remote sensing archive does not exist.
Carbon measurements	Country-specific biomass data is only available for some production forest areas. Hence, no reliable emission estimates from deforestation and forest degradation exist; only rough estimates according to IPCC Tier 1 using default values (2006 IPCC Guidelines) are available. Stand volumes were inventoried nationally 1993-1999 for different forest categories and for all species with DBH ≥ 10 cm based on cluster sampling.
National recommendations	
Infrastructure	**Hardware and Software to enable data processing and the application of GIS and remote sensing techniques is required**. Internet speed analysis suggests decent accessibility that should be enhanced to ensure sustained data access. **Institutional capacity and cross-sectoral coordination needs to be strengthened** to control (illegal) logging and promote sustainable management. Responsibilities need to be distributed clearly between concerned government agencies.
Human resources	**Training is needed to facilitate the use of GIS and remotely sensed data**, including processing of radar data**. Knowledge transfer is needed to foster sustainable management of forests** and improve efficiency of existing agriculture systems to lower pressure on forested lands. More personnel will be necessary to implement appropriate activities. Human resources also are needed to develop and implement a national biomass/carbon inventory and analyze the respective data.
Annual forest area change monitoring	**Laos needs resources to improve its capacity of remote sensing**. Annual wall-to-wall coverage can be achieved when radar data is used complementary to optical remote sensing data to fill data gaps that result from cloud coverage.
Carbon measurements	Current inventory efforts are focused on production forest. This includes the **establishment of** several hundred **permanent measurement plots all over the country**. Relations between stand volume and biomass need to be established**. It is recommended to extend the application of the inventory methodology** beyond Laos' production forests **to include all forested areas of the country**. Until now, only area change is assessed and forest degradation cannot be estimated, neither can carbon loss related to degradation or deforestation. Tier 2 reporting will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Liberia	***Land area: 96.320 km² (FRA 2005)*** ***Forest cover: 32,7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	For Liberia, national forest change information is available covering the past two decades. External deforestation analysis (1986-2000) was done by Conservation International (CI) based on Landsat imagery (Liberia's Forest Re-assessment Project). This mapping effort is currently updated in cooperation with South Dakota State University (SDSU) and CI. Different deforestation rates are reported for Liberia ranging from moderate (0,35 % by CI) to high (1,8 %, FRA 2005). In 2005, Liberia has implemented a ground-based monitoring strategy based on a sample of 703 permanent forest plots, with support of the German Forest Service (through the World Bank). Every five years, re-measurement of these plots is planned (provided that funding is available).
Responsible institutions	In Liberia, the Forestry Development Facility (FDA) is responsible for forest monitoring and inventories, and FRA reporting. Liberia has prepared a REDD Submission and an R-PIN to participate in the FCPF. Liberia has not yet submitted a National Communication to UNFCCC, but a national GHG inventory (supported by UNEP) has recently been completed. Liberia does not participate in a GOFC-GOLD regional network.
Available remote sensing data	Landsat data for the past two decades (80s, 90s, 00s) and radar data (ALOS) are available in house. Current Landsat receiving stations does not cover Liberia, therefore Landsat TM-5 imagery will not be available for future monitoring. Liberia experiences very high cloud cover. The average annual cloud cover probability is 80 %, lowest in July and August.
Carbon measurements	An external forest inventory is available (1989) measuring growing stock, but no below-ground biomass or organic carbon measurements have been made to date.
National recommendations	
Infrastructure	FDA has significant GIS capacity in-house. Further **hardware and image processing software needs to be put in place to ensure a regular forest monitoring system** i.e. data storage, processing and analysis. Internet speed is moderate; improvement of the internet connection will ensure enhance data access.
Human resources	Technical and financial support is needed to **increase the coordination and decision making capacity among institutions working on monitoring**. Human capacity and **expertise is needed for processing satellite remote sensing data and forest cover change analysis, and** . Expertise is needed to integrate radar data in the monitoring system. Expertise is required to monitor forest degradation.
Annual forest area change monitoring	**SPOT (Landsat and CBERS data when available) data are recommended as primary optical data source and should be applied to start the regular monitoring**. Due to the high average cloud coverage**,** radar data may need to be integrated to achieve full coverage on an annual basis. Remote sensing analysis have to consider seasonality issues (phenology and cloudiness).
Carbon measurements	A national plot system has been established already following a national stratification scheme. **Financial and technical capacity is needed to undertake the field measurements and laboratory analyzes** in a regular manner. Improved technical and human capacities are needed for this purpose. Soil carbon analysis suggests that soil is an important carbon pool for Liberia and an assessment should be done how significant emissions are and how to best monitor them on the national level.

Madagascar	***Land area: 581,540 km² (FRA 2005)*** ***Forest cover: 22.1 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	National level analyses of deforestation have been irregular and often initiated by donor-driven projects. The most recent data available was completed in 2007 by Conservation International's analysis of 1990-2000 deforestation rates and a subsequent update for the period 2000-2005. Deforestation rates vary within the country but declined in all parts to an average about 0.3% (FRA 2005) – 0.5% annually for the period 2000-2005. For several smaller areas of Madagascar analyses that are more detailed have been done. Deforestation statistics considering a detailed habitat classification are available based on the 22 administrative regions of Madagascar (generated from same data set for 1990, 2000, 2005).
Responsible institutions	Forest inventories and forest statistics are under the responsibility of the Ministère de l'Environment, des Eaux et Forêts et de Tourisme (MEEFT), which also reports to the FAO. The Office National pour l'Environment (ONE) is in charge of environmental monitoring and manages the national environmental information system, whereas the Directorate for Environment, Water and Forests (DGEEF) supervises forestry and forest conservation. Madagascar is highly engaged in the REDD process (National Communication to the UNFCCC, participation in joint submissions to SBSTA, preparation of R-PIN to FCPF) and participates in the Southern African Fire Network (SAFNet).
Available remote sensing data	National analysis was based on the interpretation of Landsat images from 1990, 2000 and 2005. CBERS data is not available at full coverage (83%). The cloud free proportion of SPOT imagery is rather small (62% averaged for 2006-2008). Mean annual cloud coverage amounts up to 50%.
Carbon measurements	Carbon emission from LULUCF were provided within UNFCCC National communication (2000: 45,5 million tonnes CO_2 equivalent to about one fifth of the total emissions); however, these estimates are currently revised.
National recommendations	
Infrastructure	**Additional resources will be necessary to establish a country-wide monitoring system** adequate to deliver annual updates and consider degradation. Capacity building and **strengthening of institutions is necessary to ascertain professional policymaking, technical support and implementation of monitoring strategies**. One focus should be the topic of decentralization of forest management, particularly incorporating the participation at community level. Internet connectivity should be improved to enable proper data access.
Human resources	GIS and remote sensing specialist as well as capacity to implement biomass and carbon monitoring are available, however further training is required to develop appropriate methodologies and standards. In addition, **capacity building is necessary for proper monitoring and management of forest resources** at all governance levels, especially considering local forest communities entrusted with forest management. **Human resources** in particular **need to be scaled up in the sector of forest policy/law and governance** to develop a national effective legislation, monitoring and management framework.
Annual forest area change monitoring	Madagascar is regularly covered by **Landsat**, which **should be the primary source of remote sensing data**. Given the degree of mean annual cloud coverage and its high variability within the extent of Madagascar, an annual wall-to-wall coverage is very likely to require **the adoption of radar imagery in some regions** as additional data source. Monitoring of degradation is not feasible without fine resolution remote sensing data and demands extra capacity.
Carbon measurements	**A national forest carbon inventory system needs to be established**. Therefore, the implementation of human and technical resources is needed for fieldwork, measurements as well as data analysis and interpretation. Tier 2 reporting will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Malaysia	***Land area: 328.550 km² (FRA 2005)*** ***Forest cover: 63,6 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Malaysia has developed a continuous Forest Resources Monitoring System. In 1984 Malaysia implemented the National Forestry Act which is responsible for defining and recognizing forest areas and provides the Permanent Forest Estate (PFE) for classification issues. Since 1996 the European Union has been providing financial and technical assistance to support the Malaysian Government initiatives to develop their computerized information and mapping system. There is regional variation in the availability and quality of inventories.
Responsible institutions	In Malaysia the responsible institution for planning, management and monitoring of the forestry sector is the Forestry Department. The Malaysian Remote Sensing Agency is capable of performing state of the art analyses using a broad range of satellites data sources. Malaysia has submitted a GHG inventory for LULUCF (tier 1) to UNFCCC in 2000 and has submitted views on REDD to the UNFCCC SBSTA. Malaysia is engaged in the GOFC-GOLD SEARRIN Regional Network and has indicated interest in participating in the World Bank FCPF initiative.
Available remote sensing data	Malaysia is regularly covered by Landsat TM & CBERS. For monitoring land cover satellite imagery, basically Landsat TM for the establishment of a fixed grid of monitoring points over the entire forested area is used. Additional field sampling on a continuous basis, of all the forest types on a randomly selected number of grid points according to predetermined accuracy standards is done.The country experiences persistent cloud coverage. In the long-term yearly average, more than 85,77 % of the country is covered by clouds.
Carbon measurements	Carbon stocks were estimated using Tier 1 factors in the FAO FRA 2005. These values have been used for FRA and UNFCCC reporting. Permanent measurement plot exists, but there is some inventory capacity.
National recommendations	
Infrastructure	Technical capacity (hard- and software) for image processing and analysis, and forest measurements is good and institutions are resourced.
Human resources	The institutional capacities, staff number and technical skills to implement forest monitoring in Malaysia is good. Additional **human capacity is needed to undertake consistent forest carbon monitoring** i.e. more technical staff and technical training field measurements and forest degradation.
Annual forest area change monitoring	A national monitoring system for land use, land cover and forest cover exists in Malaysia. There is need to establish a sustained system monitoring forest degradation and its carbon impacts
Carbon measurements	**Inventories** on a regular basis are available for peninsular Malaysia but **need to be updated for Sarawak and Sabah regions**. Adequate capacity building can be accomplished in-country. **Capacity building to enable country-wide biomass and carbon pool reporting according to IPCC Tier 2 is required**. Occurrence of high carbon soils in swamp forest areas supports the explicit recommendation to **include a soil carbon inventory in the national monitoring and inventory strategy** and further investigate carbon storage in concerned ecosystems. Thorough Tier 2 carbon reporting will require: - Identification of national carbon stock key categories - Develop country-specific sampling design and stratification covering entire Malaysia - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Mexico	***Land area: 1.908.690 km² (FRA 2005)*** ***Forest cover: 33,7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	In Mexico national forest monitoring includes analysis of remotely-sensed data to identify changes in land cover at regional/national level using MODIS. National Forest Inventory will be updated every year based on re-measurement of 20% of all permanent sampling sites. Monitoring process includes enrolled areas, based on the analysis of high resolution satellite imagery like IKONOS, QUICKBIRD or Spot. It is carried out at least three times in a five year period, to verify compliance with forest cover conservation. In some cases, when no satellite data is available, monitoring is complemented with field surveys.
Responsible institutions	For national forest monitoring and forest inventories CONAFOR is responsible for implementing forest monitoring and forest inventories. The National Institute of Statistics, Geography and Informatics (INEGI) is responsible for developing land use and vegetation cover (LULC) maps at the national scale. Mexico is strengthening environmental institutions. The Mexican Carbon Program (a network of research institutes and universities) is involved in carbon related research. Mexico has submitted a National Communication to UNFCCC (including a GHG inventory for LULUCF, tier 1) and prepared an R-PIN for the FCPF.
Available remote sensing data	Mexico is nearly regularly covered by Landsat TM (93,37 %) & CBERS (100,00 %). First aerial photographs are available with the beginning of the 1970s. Since 1983 the generation of land use and land cover maps is based on Landsat imagery and paper maps. At this time MODIS data and high resolution Spot images were used. A broad range of remote sensing data is available and all optical sensors are sparsely affected by cloud cover. Future developments of satellite imagery, such as radar imagery that can be used to develop 3D vegetation structure maps will be available through an agreement between Mexico and Germany. A monitoring system, which incorporates various satellite imagery with efficient ground truthing will be developed to detect deforestation and forest degradation.
Carbon measurements	Annual emissions related to land use/land cover and forestry during the period from 1993 to 2002 were estimated at 86.7 million tonnes of CO_2 per year but with known high levels of uncertainty. At the end of 2009 an updated GHG inventory will be available for the years 2002 to 2007. Mexico is also collaborating with Canada to evaluate the feasibility to apply the Canadian Forestry Service Carbon model (CBM-CFS) to the Mexican forestry sector.
National recommendations	
Infrastructure	Technical capacity (hard- and software) is available for image processing and analysis but may need to be updated when moving to a national carbon accounting and for annual monitoring. **Capacity for accuracy assessments and error analysis is required to assess existing data sources and ensure continuous monitoring over time**.
Human resources	The institutional capacities, staff number and technical skills to implement forest monitoring in Mexico is partially limited. Therefore, additional **human capacity development is needed to undertake regular forest monitoring and in the context of carbon measurements, addressing degradation for national estimation and international reporting.**
Annual forest area change monitoring	**The national monitoring system is in progress and needs to be established as a continuous program**. Regarding this issue, partnerships to Germany, Brazil and Canada have been established and should be fostered.
Carbon measurements	**The national forest inventory needs to be improved towards a national carbon stock and carbon stock change measurements system**. This requires the necessary technical and human resources field work, measurements as well as the data interpretation and analysis.

Nepal	***Land area: 143,000 km² (FRA 2005)*** ***Forest cover: 25.4 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Forest area change is not monitored regularly in Nepal. Current estimates of forest cover and deforestation build only on a small number of studies without standardized methodologies resulting in constrained comparability (spatially and temporally). The monitoring of forest degradation, which is of high intensity in national forests, is inadequate. Major reasons identified are the lack of clarity in the tenurial system and the need of fuel wood and fodder. Within the FRA 2005 report the FAO quantified forest area loss in Nepal at 1.4% annually for the period 2000-2005.
Responsible institutions	The responsibility for forest monitoring and forest inventories is under the Ministry of Forests and Soil Conservation (MFSC), the Department of Forest Research and Survey (DFRS), the District Forest Offices and the Community Forest User Groups (for respective handed over forests). MFSC and the Department of National Parks and Wildlife Conservation are in charge of forestry and forest conservation. FRA reporting is done by the DFRS. The REDD engagement of Nepal is rated high (UNFCCC National Communication, REDD submissions to SBSTA, R-PIN to FCPF).
Available remote sensing data	The first historic data set covering the entire country is based on aerial photographs from 1978/79. Forest cover was assessed again in 1990s based on aerial photographs and Landsat TM imagery. Recent CBERS and Landsat data are available for the entire country, but data quality is affected by rather high degree of cloud coverage (53% mean annual) characterized by moderate in-country variability and pronounced seasonality. Additional difficulties for the processing of remotely sensed data result from the mountainous Nepalese terrain.
Carbon measurements	First national inventory in the 1960s without coverage for high Himalayan region and considerable gaps concerning the hill region, update for 1986 and latest inventory refers to 1994. However, there is a lack of consistency for the data set at national level, since methods were different for several areas. There is no carbon accounting for forest carbon pools other than above-ground biomass in Nepal. A reliable estimate of carbon emissions from deforestation and forest degradation is not available.
National recommendations	
Infrastructure	Institutional structures must be adapted to address deforestation and forest degradation in the context of ownership, tenurial rights and management responsibility. **Participation of local communities in forest management** already showed promising results in terms of avoidance/reduction of deforestation and forest degradation. This approach **should be expanded** and **an adequate legal framework** (promoting sustainable management, preventing illegal logging) **should be established**. **Hardware and Software to implement a monitoring system** designed to meet the demands of REDD **is required**. Internet connection speed is moderate providing decent potential regarding data accessibility.
Human resources	**More human resources will be necessary to enable a regular forest monitoring**. **Capacity building is needed for monitoring forest degradation processes and the assessment of carbon stocks**. Experiences with optical remote sensing data exists, the use of radar data may require additional capacity.
Annual forest area change monitoring	**A nation-wide monitoring system using consistent methodology is needed**. A baseline (regarding vegetation types, forest area and status) needs to be established based on such a harmonized approach for the whole country. Given the degree of cloud coverage, radar data may complement Landsat-type data to achieve annual wall-to-wall coverage. In the light of the steep mountainous terrain covering a large proportion of Nepal, topography complicates the use of remote sensing techniques. Considerable parts of Nepal's forest area are affected by fire (17% long term average) for which reason **the integration of a fire monitoring system should be considered**.
Carbon measurements	Until now no permanent sample plots were used for the forest inventories. **The adoption of the permanent plot method for future forest inventory activities is recommended**. Furthermore, Nepal should **establish a consistent methodology for the assessment of biomass** within its national inventory strategy and revise the forest management operational plans to meet the requirements of forest degradation monitoring. Tier 2 reporting will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Nigeria	***Land area: 910,770 km² (FRA 2005)*** ***Forest cover: 12.2 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	The monitoring of forest and protected areas in Kenya is generally fragmentary. Forest cover statistics were based on partially national forest inventories in 1977 and 1994. Integration between central institutions (such as a national forest inventory) and regional capacity is difficult. The deforestation rate is estimated at 3.3% annually for the period 2000-2005 and is one of the highest observed worldwide.
Responsible institutions	Federal Department of Forestry (FDF) working with the National Government (Federal Government of Nigeria) is responsible for planning, management and monitoring the forestry sector. Also the State Forestry Department (SFD) is in charge with the state government provides and collects information about the forestry sub-sector. Additional work is done by the Forestry Research Institute of Nigeria(FRIN). Nigeria generally has a low REDD engagement.
Available remote sensing data	Nigeria lacks access to Landsat data like other central African countries due to the absence of a satellite receiving station in the region.
Carbon measurements	Growing stock was estimated only for production forests and plantations, according biomass and carbon estimates are based on IPCC default values. NFA formulated
National recommendations	
Infrastructure	**Technical capacity** (hard- and software**) is required** for image processing and analysis. Internet connectivity is very slow, better internet access needs to be established to improve data access or other means should be implemented (i.e. DVD delivery).
Human resources	The institutional capacities, staff number and technical skills to implement forest monitoring in Nigeria is limited. Therefore, **human capacity is needed to undertake regular forest monitoring** i.e. more technical staff and technical training for processing and analyzing of remote sensing data to assess forest area change.
Annual forest area change monitoring	**A national monitoring system** for land use, land cover and forest cover **needs to be established** in Nigeria. A central African receiving station for Landsat would provide an essential data source for Nigeria; availability of CBERS data can be checked, SPOT imagery (although limited by persistent cloud cover) may provide another option to make use of optical remote sensing data. In addition, radar data should be used to fill data gaps. Regarding this issue, political and institutional obstacles have to be overcome.
Carbon measurements	**A national forest carbon inventory needs to be established** and requires the necessary technical and human resources to conduct fieldwork, measurements as well as data interpretation and analysis. Carbon reporting according to Tier 2 will require: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Panama	***Land area: 74,430 km² (FRA 2005)*** ***Forest cover: 57.7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Currently, there is no permanent forest monitoring system established in Panama. Land cover and land cover change is assessed every 8 years. A forest cover change map is available for the period 1992-2000 stating an annual loss of 1.1% on average. FAO reports significantly lower values (0.2% for 1990-2000 on average) FRA 2005 report specifies the annual forest area loss at 0.1% for the period 2000-2005. An update for the existing maps (1992, 2000) representing the forest cover of 2008 is planned to be published soon.
Responsible institutions	ANAM (Autoridad Nacional del Ambiente - National Authority of the Environment) is the institution responsible for monitoring the country's forest coverage, to conduct forest inventories and FRA reporting to the FAO. Panama shows a high engagement for the REDD initiative (National Communication to the UNFCCC, several joint submissions to SBSTA, R-PIN and draft R-Plan to FCPF), and is designated pilot country in the UN REDD programme.
Available remote sensing data	Landsat and Aster imagery was used already for land (forest) cover monitoring. Currently, the country area is not covered by Landsat since a receiving station is not present in the region. CBERS data is however available for entire Panama. An important constraint of optical remote sensing data is the mean annual cloud coverage of 82%. Hence, also SPOT data is severely affected by clouds to an extent that not a single cloud-free set is available for any given year during the historical period 1990-2005, and only 32% of the country area is free of clouds on average for recent years (2006-2008). Panama (jointly-)operates a monitoring system (SERVIR – Regional System for Visualization and Monitoring) that provides data on active forest fire since 2005 in near real time (ca. 45 min lag) based on a fire detection system installed by NOAA. It is based on data delivered by GOES, POLAR, MODIS and DMSP satellites.
Carbon measurements	Panama provided a GHG emission estimate from the LULUCF sector in its first National Communication to the UNFCCC for the reference year 1994 based on 1996 IPCC guidelines. Updated values will be reported in 2009 for the reference year 2000 (based on 2003 IPCC GPG). Preliminary data suggests that land conversion still is the principal source of GHG emissions in Panama. The fire monitoring system enables estimates of GHG emissions from forest fires. A recent consistent national forest inventory does not exist; several inventories of various areas of variable size are available that use different methodologies, relate to different reference years and are characterized by different uncertainties. Hence, the only (nearly) national inventory covering various regions of Panama is from a collaboration with the FAO in 1972.
National recommendations	
Infrastructure	Forest law enforcement should be improved which will require considerable effort to **increase technical capacity to make use of advanced methodology from remote sensing and GIS**. Institutional and technical capacities should also be improved to enable a reliable coordination for the monitoring and management of forests in Panama (to ensure data access among participating agencies and stakeholders, and to clearly distribute responsibilities). Internet connectivity is comparatively good and should not hamper data access.
Human resources	Additional **human resources will be necessary to develop and implement a standardized national monitoring and inventory strategy** meeting the requirements of REDD. ANAM staff needs to be enlarged and training for data collection, interpretation and analysis is essential. Of particular interest for Panama on the technical side may be **capacity building for the application of radar data**. To promote sustainable management of forest resources, capacity building on the level of local communities will be necessary.
Annual forest area change monitoring	Current 8-year monitoring interval is too long, Panama aims for a 3-year interval. More frequent updates could be realized by a systematic sampling approach. **The integration of CBERS data into the national monitoring system should be investigated**. However, cloud cover is a serious issue in Panama and **the use of Radar data is highly recommended** to achieve the required annual coverage.
Carbon measurements	Panama states to currently **update and systematize** its **national forest inventory** to provide, inter alia, reliable information on biomass stocks. It appears that much work has still to be done to achieve this, including the assessment of historical data sources to establish a baseline. The monitoring of forest biomass via NDVI (as envisaged by Panama) is not recommended since reliable estimates cannot be expected due to signal saturation at low biomass stocks. Panama should **establish permanent measurement plots to assess biomass and carbon stocks** and apply the following steps to ascertain carbon reporting according to IPCC Tier 2: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: Allometric data (for biomass conversion and expansion), Carbon fraction values considering country-specific stratification, Disturbance matrices tracking transfers between carbon pools

Papua New Guinea	***Land area: 452,860 km² (FRA 2005)*** ***Forest cover: 65.0 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	The deforestation rate of PNG is estimated at 0.5% annually for the period 2000-2005 (FRA 2005). However, more pronounced loss of forest due to agriculture and extensive degradation due to overcutting in forest concessions can be observed locally. Forest cover maps for 1975, 1996 and 2002 are available. The PNG Forest Authority uses a forest inventory mapping system developed by external consultants.
Responsible institutions	Department of Environment and Conservation (DEC) and the PNG Forest Authority (PNGFA) are the key institutions responsible for forest monitoring and inventories, forestry and forest law enforcement. Further contribution is provided by the Forestry Research Institute (FRI) and the Remote Sensing Center of the University of Papua New Guinea. PNG is highly engaged in the REDD initiative (National Communication to UNFCCC, participation in joint submissions to SBSTA, draft R-PIN submitted to FCPF), and is designated pilot country in the UN REDD programme. FAO reporting for FRA 2005 was done by the PNGFA.
Available remote sensing data	National capacity concerning the application of remote sensing data is limited. The national forest inventory mapping system incorporates aerial photography and satellite imagery from 1975 an 1996 respectively but was developed external. Landsat TM imagery is available for the entire country but the use of optical remote sensing data is substantially limited by persistent cloud cover (mean annual of 87%).
Carbon measurements	National forest inventory data is available but forest inventories were carried out by external consultants. Growing stock volumes were estimated, but information on biomass and carbon stocks is lacking. GHG emissions from forestry were not reported within PNG's National Communication to the UNFCCC (2002). A first estimate of GHG emissions from deforestation and forest degradation was published in a recent academic study, however the methodology used was not IPCC-compliant and results are considered to be only indicative.
National recommendations	
Infrastructure	**Technical resources are required to implement a comprehensive monitoring and inventory strategy** meeting the demands of REDD. This comprises hardware and software to establish a national monitoring system for deforestation and forest degradation activities, i.e. appropriate to process the amount of required data as well as equipment to implement reliable in-situ measurements. Internet speed analysis suggests that improvements are required to enable proper access to available data sources and to ensure exchangeability of data across participating governmental agencies, local communities and other stakeholders.
Human resources	Extensive capacity building is needed in terms of training – also to enable a meaningful participation of local communities (which are principal landowners). **Knowledge and skills for monitoring and inventory practices and sustainable management are required**. More capacity is needed also for the enforcement of forest law. Capacity building for remote sensing application should consider training to process radar data.
Annual forest area change monitoring	Landsat TM imagery can help to provide the remote sensing data framework for forest area change analysis, however it will be essential to **complement any optical remote sensing imagery with radar data** to facilitate annual wall-to-wall coverage of PNG, to enable timely monitoring of illegal logging threats or forest fires, and to detect possible leakage for any kind of carbon offset project.
Carbon measurements	**A national forest carbon inventory needs to be established** and can benefit from a n existing network of permanent sample plots. Consequently, the implementation of human and technical resources is needed for fieldwork and measurements as well as data analysis and interpretation. The occurrence of swamp forests in PNG storing massive amounts of carbon in soil supports the explicit recommendation to **include a soil carbon inventory**. Tier 2 reporting will require the following steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Paraguay	***Land area: 397.300 km² (FRA 2005)*** ***Forest cover: 46,5 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Land cover products are available based on Landsat, prepared by external donors (FAO/GTZ 2002, Japanese International Cooperation Agency 1999), with limited accuracy. Monitoring is done on regional level, but no national system is in place. Various deforestation estimates exist. In FRA 2005, Paraguay reported an annual deforestation rate of 0,9 % of forest area. Major deforestation drivers and causes are known. Local NGOs support government institutions in forest monitoring.
Responsible institutions	National Forest Institute (INFONA) and Secretary of Environment (SEAM) are responsible for forest monitoring and inventories, supported by local NGO's. INFONA is responsible for FRA reporting. The engagement of Paraguay in the REDD process is very high (UNFCCC National Communication (including GHG inventory for LULUCF, tier 1), several REDD submissions, R-PIN to FCPF).
Available remote sensing data	MODIS data are available in the governmental institutions. Paraguay is regularly covered by Landsat/CBERS. Historical cloud free SPOT data are available for 2002 covering more than 70 % of the country, much less is available for the 90ies and since 2002. Mean annual cloud coverage is more than 50 %
Carbon measurements	No national forest inventory data are available. In its first UNFCCC National Communication, a GHG inventory for the LULUCF sector was provided, using Tier 1 default values. Currently, a second GHG inventory is in preparation (more than 50 % complete), supported by UNDP.
National recommendations	
Infrastructure	**Improve technical resources and data access procedures:** Building upon existing hard- and software, additional technical resources are needed to implement operational forest monitoring. Internet speed analyses suggest that data access is very slow, this needs to be improved or other means of regular data access explored. National IPCC reporting requirements suggests that all relevant data should be made available in a national forest carbon information system.
Human resources	SEAM has good GIS and remote sensing team, but **more human capacity is needed to undertake regular forest area change analyses building upon remote sensing and GIS knowledge in responsible institutions**. Capacity needs to be build for working with different type of remote sensing data (optical and potentially radar). Technical capacity building is needed for monitoring forest degradation processes.
Annual forest area change monitoring	**Use available remote sensing data to monitor historical forest changes and establish system for future efforts**. Landsat/CBERS should be the primary source of remote sensing data. Additional radar data may be needed to achieve annual wall-to-wall coverage.
Carbon measurements	**A national forest carbon inventory needs to be established.** Therefore, the implementation of human and technical resources is needed for field work, measurements as well as the data interpretation and analysis. Establishment of national forest carbon inventory for Tier 2 reporting is needed: - Identification of national key categories - Develop sampling design and national stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Peru	***Land area: 1.280.000 km² (FRA 2005)*** ***Forest cover: 53,7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Peru monitors forest cover by the Forest Intendance (part of the Agricultural Ministry) which is responsible for the monitoring activities and forest management. Emphasis is given to the fulfilment of the commitments acquired in the forest management contracts. The forest area monitoring capabilities are limited and not of full national coverage. A Map of Deforestation in the Amazon region (2000), which was developed by using 329 1:100,000 maps and 45 Landsat images (1:250,000) was produced. Additionally, there is a deforestation map (base 2000) recalculated by using the same methodology for inventories with the year base 2000.
Responsible institutions	In Peru the Ministry of Environment (MINAM) is in charge of the establishment, implementation and control of the national and sectoral environment related policies. MINAM mission addresses environmental conservation for sustainable, rational and ethical use of national resources and realms. MINAM is in order to coordinate the implementation of REDD mechanisms, and to establish the national inventories of greenhouse gases. In the frame of this role, it is already developing the necessary designing and inter-institutional coordination and agreements, including those for deforestation monitoring processes. Furthermore the Ministry of Agriculture (MINAG) is the authorized entity for the national level policies and control of the agrarian sector. MINAG is also the national authority for forestry and wildlife matters, and promotes its conservation and rational use or exploitation. There are also other forest cover monitoring initiatives done by different organizations Peru prepared a R-PIN for the FCPF.
Available remote sensing data	Peru is regularly covered by Landsat TM & CBERS. For forest area change and deforestation mapping Landsat images were used. In the long-term yearly average, 70,90 % of the country is covered by clouds and may challenge full annual coverage with current optical systems.
Carbon measurements	According to the National Inventory of Greenhouse Gases Effect (2000), the LULUCF emissions are measured and Carbon stock values have been reported for FRA 2005 using Tier 1 default values. Emissions from land LULUCF represent 47% of total emissions at the national level. Calculations have been done by IPCC standards, using default calculation factors for carbon stocks; however, studies on natural ecosystems in the Peruvian Amazon indicate that the latter are higher than IPCC standards.
National recommendations	
Infrastructure	**Technical capacity (hard- and software) is required for image processing and analysis**. Internet connectivity is rather slow, better internet access needs to be established to improve data access.
Human resources	**Institutional capacities, staff number and technical skills to implement a forest monitoring system in Peru need to be strengthened**. There is need to develop a strategy to clarify the roles and responsibilities of each stakeholder according to legal regulations for identifying institutional gaps that will need to be incorporated in the Organizations and Functions Regulations of different organizations in order to implement the National Strategy. A national REDD planning process has started and respective consultations “in situ” will be done through regional workshops in selected areas.
Annual forest area change monitoring	**Landsat/CBERS provide the primary source of remote sensing data and should be used to implement a regular forest monitoring system.** Additional radar data should be used to fill data gaps. Technical and financial support is required for identification and quantification of causes or drivers of the deforestation by region, direct causes as well as indirect that influence the deforestation and/or degradation of forests. In April 2008 two initiatives at local sample sites were started. This information will be compared with existing maps of deforestation, protected areas, native communities, forest concessions, biodiversity, endemism, conservation high value areas, endangered species, among others.
Carbon measurements	**A national forest carbon inventory needs to be established** and requires the necessary technical and human resources fieldwork, measurements as well as the data interpretation and analysis. Steps for moving to Tier 2: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification - Expertise to estimate historical emissions from deforestation and degradation

Suriname	***Land area: 156.000 km² (FRA 2005)*** ***Forest cover: 94,7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	A Forest cover map for 1998 has been produced based on Landsat imagery by national institutions with support from FAO. There is no time series of classified remote sensing data available to monitor changes in forest cover. Historical deforestation rates are very low (less than 0,1 % per year). Currently, a new monitoring system is in development combining optical and radar data (ALOS). A partnership has been established with the Netherlands, the Guiana Shield Initiative and the JAXA-Kyoto Carbon project. A historical forest cover time series (including radar data) is being developed by the partners. The technical expertise will be transferred to Suriname. Basic knowledge on GIS is present.
Responsible institutions	In Suriname three institutions are responsible for forest monitoring and inventories: - Forest Service of the Ministry of Physical Planning, Land and Forest Management (LBB) - Foundation for Forest Management and Production Control (SBB) - in future: Forest and Nature Management Authority (BOSNAS) Suriname is highly engaged in the REDD process. It has submitted a National Communication to UNFCCC (including a GHG inventory for LULUCF using tier 1), a REDD Submission, and prepared an R-PIN to the FCPF. Suriname participates in the Amazon Regional Network.
Available remote sensing data	Aerial photos are available for entire Suriname. Historical Landsat and CBERS data are available in-house. The average cloud cover probability is 78 %. Only limited cloud free SPOT coverage (35 % of country) is available in the archives. Suriname has access to radar data (ALOS) that are processed and analyzed in cooperation with support from the Netherlands (Wageningen University and SARvision).
Carbon measurements	Two national forest inventories were conducted in Suriname, 1971-1974 by FAO and in the mid 1990s by the Department of Natural Resources and Environmental Assessment (NARENA). In concession areas, field measurements are taken periodically. Limited forest inventory capacity exists from periodical inventories in small areas but there is no systematic national forest inventory system that directly monitors forest biomass and FRA 2005 reporting used default values equivalent to IPCC Tier 1.
National recommendations	
Infrastructure	Improved **institutional capacity is needed to carry out regular forest inventories and forest mapping**. Basic technical equipment is needed i.e. hard- and software for satellite data interpretation as well as equipment for field measurements.
Human resources	For a regular monitoring system, more human capacity is required. Technical **capacity for processing and interpreting remote sensing data must be built** and strengthened. Possibilities for training in forest monitoring with both optical and RADAR data have been established together with partners (see above). Building upon present basic GIS knowledge, the improvement of data management skills and **GIS analysis skills require improvement**. Furthermore, **knowledge is needed on how to measure and monitor biomass and carbon stocks**.
Annual forest area change monitoring	**Expertise is needed to develop a national strategy for regular forest monitoring and, subsequently resources are needed for implementation**. Radar data are needed in addition to optical data to achieve full country coverage. The necessary knowledge is developed by partners and will be transferred to Suriname. It will then be important to ensure that this expertise is used to implement a regular national monitoring system. In Suriname, deforestation and degradation occurs in scattered small-scale patterns. Monitoring must be able to detect these changes, perhaps based on high resolution data.
Carbon measurements	There is a need **to install a continuous, systematic and standardized national inventory approach** to quantify above-/belowground carbon and soil carbon. Relevant governmental agencies need capacity building for biomass monitoring activities, carbon accounting and implementing measurement plots. Further steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification

Tanzania	***Land area: 883,590 km² (FRA 2005)*** ***Forest cover: 39.9 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Several land cover/land use maps are available for different regions of Tanzania. For eastern Tanzania 2,800 forest plots and 500 km of forest disturbance transects were assessed with help of the GEF. According to FAO, Tanzania collaborates with NFMA and its NFA is implemented but not yet completed. A National Forest Database (NAFOBEDA) and a National Forest Assessment and Monitoring Programme (NAFORMA) have been established. FAO estimates the deforestation rate at 1.1% of forest cover annually for the 2000-2005 period.
Responsible institutions	The Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT) is responsible and coordinates monitoring, forest inventories and law enforcement. FRA reporting is in charge of the Tanzania Forestry Research Institute. The country is highly engaged in the REDD process; Tanzania prepared a R-PIN to the FCFP, a national communication to the UNFCCC and participates in the Southern African Fire Network (SAFNet) as well as in the Miombo Network, and is designated pilot country in the UN REDD programme.
Available remote sensing data	Landsat data is available for the whole country area, CBERS covers about 73% of Tanzania. Availability of good quality imagery may be constrained by the high degree of mean annual cloud coverage (55%). Sokoine University of Agriculture and Ardhi University are supposed to have remote sensing maps available at 5 years intervals since 2000 and 1990 respectively.
Carbon measurements	National carbon emissions from deforestation and forest degradation in Tanzania are unknown. Smaller scale studies were conducted for the Eastern Arc Mountains and lowland coastal forests, and for a few of the reserved areas of woodlands. It is estimated that 500,000 ha of forests and woodlands are degraded annually but the impact on carbon stocks is unknown. No thorough national forest inventory data is available. In the period 1971-73 FBD inventoried natural forests and woodlands in Mtwara, Kilimanjaro, Tabora, Tanga regions and in the Kilombaro district. However, Tanzania is working on conducting a national forest inventory in partnership with FAO's NFMA project until 2010. GHG inventory has been reported to UNFCCC based on Tier 1.
National recommendations	
Infrastructure	**Strengthened coordination between institutions and sectors from local to national level is required** (considering policy and administration, management, NGOs, local communities and other stakeholders). The **technical capacity has to be enlarged to implement monitoring and inventory strategies** effectively, that includes the poor internet connectivity, which requires improvement to ensure data access. National forest policy and law should be adapted to promote sustainable management of forest resources in Tanzania considering collaboration with local communities and NGOs.
Human resources	Adequate **augmentation of forestry staff** needed to carry out forestry programmes and capacity development for professional, technical and specialized competence is required on national and district levels.
Annual forest area change monitoring	**Landsat data can be used as primary data source and should be used in continuous and consistent manner for national forest area change monitoring.** Since Tanzania is regularly affected by fires (16% of forest in long term average), **a fire monitoring system is recommended**. In view of high estimates of areas affected by forest **degradation** a **monitoring programme is recommended** which will require fine resolution remote sensing imagery.
Carbon measurements	NAFOBEDA cannot detect degradation. A degradation model for eastern Tanzania is in development but further **effort is needed to assess the impact of degradation on carbon stocks**. Tanzania needs technical and financial resources to implement NAFOBEDA **and enable forest monitoring on a countrywide basis**. Further steps will enable reporting at Tier 2: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification o Disturbance matrices tracking transfers between carbon pools

Vietnam	***Land area: 325,490 km² (FRA 2005)*** ***Forest cover: 39.7 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Monitoring of forest cover (through the National Forest Inventory Monitoring and Assessment Program, NFIMAP) follows a 5-year cycle and has been started in 1991. Vietnam jointly uses remote sensing and field data. Degradation is considered a serious issue in Vietnam and has been observed in all regions. Deforestation and forest degradation are driven by the high demand from the timber/timber processing industry and the conversion of forest land for cash crops but also by the construction of hydro power plants and the domestic demand from indigenous communities. The annual forest area change rate (2000-2005) has been estimated as 2.0% per year, indicating a considerable increase in total forest area. However, this increase is mainly attributed to expanding plantation forests, regenerating grass/shrub land and above all to a statistical effect. Actually, a continuous loss of natural forests can be assumed for Vietnam.
Responsible institutions	The Forest Inventory and Planning Institute (FIPI) under the Ministry of Agriculture and Rural Development (MARD) is responsible for forest monitoring, inventories and also for the FRA reporting to the FAO. MARD coordinates all activities related to Vietnam's forests; other departments contributing include the Forest Protection Department (FPD) and the Department of Forestry (DOF) that provides annual monitoring reports. REDD participation of Vietnam is rated high (UNFCCC National Communication, REDD submission, R-PIN), the country is engaged in the Southeast Asia Regional Research and Information Network (SEARRIN) and formulated an NFA within the framework of FAO's NFMA project, and is designated pilot country in the UN REDD programme.
Available remote sensing data	Satellite remote sensing data from Landsat TM, SPOT and CBERS sensors are available for the entire country. The FIPI has completed three Cycles of NFIMAP (1991-1995, 1996-2000 and 2001-2005) and is currently conducting the fourth Cycle (2006-2010). Each cycle has used progressively more advanced satellite imagery. Cycle 1 (1991-1995) used 30m x 30m resolution Landsat TM imagery to make forest cover maps at scale of 1:250,000, Cycle 2 (1996-2000) used 20m x 20m resolution Spot imagery to establish forest cover maps at 1:100,000 and Cycle 3 (2001-2005) used Landsat ETM to produce forest cover maps at 1:100,000. Cycle 4 is using Spot 5 imagery with a resolution of 2.5m x 2.5m to create forest cover maps up to 1:25,000.
Carbon measurements	There is no national estimate of carbon emissions from deforestation and forest degradation available for Vietnam. Indicative values were reported with Vietnam's draft Second National Communication to the UNFCCC. Vietnam and FAO collaborate within the NFMA programme. Data for the estimation of forest biomass and forest carbon stocks is not collected within NFIMAP (with the possible exception of living biomass of forest trees, available data is inconsistent) and the existing program is inadequate for the monitoring of forest degradation.
National recommendations	
Infrastructure	**Hardware and software to conduct and analyze forest monitoring and inventory** (not only but particularly) on provincial/local level is **required**. Vietnam especially lacks capacity for the data processing, which will become even more demanding considering the necessity to integrate the monitoring of forest biomass and carbon stocks (much of the field data collected during the past inventory cycles remained unprocessed). The slow internet connectivity in Vietnam hampers data access and should be addressed.
Human resources	**Improving the forest monitoring and inventory program and related human capacities** are needed in order to be able to address forest degradation **will require a stronger information flow between national and local level**. Furthermore, the training of personnel is required to collect, process, analyze and report the additional information generated through the measurement/monitoring of biomass and carbon stocks as well as forest degradation.
Annual forest area change monitoring	Landsat TM, SPOT and CBERS data is available and Vietnam has approved a natural resources project that envisages the installation of a receiving station for SPOT 5 (and other remote sensing imagery). **Radar data may be helpful to achieve full coverage on a regular basis** given the high mean annual cloud coverage of 77%.
Carbon measurements	The **establishment of a degradation monitoring program** is essential because of the pronounced importance of forest degradation in Vietnam. There is a need to enhance the national inventory approach to integrate systematic and standardized methods for the quantification of above-/belowground biomass and soil carbon. **Relevant governmental agencies need capacity building for biomass monitoring activities, carbon accounting and implementing measurement plots**.

Further steps to achieve Tier 2 reporting:

- Identification of national carbon stock key categories
- Develop country specific sampling design and stratification
- Implement field sample plots to derive the following parameters:
    - Allometric data (for biomass conversion and expansion)
    - Carbon fraction values considering country-specific stratification
    - Disturbance matrices tracking transfers between carbon pools

Zambia	***Land area: 743.390 km² (FRA 2005)*** ***Forest cover: 45,3 % (FRA 2005)***
Current national forest area monitoring and carbon stock assessment	
Forest area change monitoring	Zambia lacks up to date forest resources information and inventories. An external forest cover map was done using NOAA-AVHRR. The historical deforestation information is not very reliable. In FRA 2005, an annual deforestation rate of 1% (2000-2005) has been reported. Currently, a National Forest Assessment is in progress, supported by FAO. It includes the production of a land cover product based on Landsat as well as field surveys at 221 permanent sample plots systematically spread across the country for field measurements.
Responsible institutions	The Forestry Department of the Government of Zambia is responsible for FRA reporting. No information was available on the responsible institution for monitoring and inventories. Zambia's engagement in REDD is relatively low. It has submitted a National Communication to UNFCCC, including a GHG inventory for LULUCF (Tier 1). A second GHG inventory supported by UNDP is in preparation. Zambia is engaged in the GOFC-GOLD Regional Networks: SAFNet and Miombo, and is designated pilot country in the UN REDD programme.
Available remote sensing data	Zambia is regularly covered by TM and CBERS. Good historical SPOT coverage is in the archives. Six years of cloud free SPOT imagery covering > 80 % of the country's area are available in the period of 1990-2005. In average, 43 % of the country is cloud covered with strong within-year variability (seasonality). In November and December the lowest cloud cover percentage is observed.
Carbon measurements	The last national inventory in Zambia dates back to 1969, followed by the Southern African biomass study in 1989. In FRA 2005, Zambia reported on three carbon stocks (AGB, BGB, and dead wood) using tier 1, while the AGB was derived based on national values but from the out-dated inventory. A new National Forest Assessment is currently in progress with the support of FAO (see above).
National recommendations	
Infrastructure	Internet connectivity is relatively slow, better internet access needs to be established to improve data access or alternative data access procedures would need to be established. Financial **support is needed to provide the necessary remote sensing and GIS hard- and software** in relevant institutions.
Human resources	Building on the expertise that is provided within the ongoing FAO NFMA, **human capacity and comprehensive expertise is needed for satellite based forest change analysis** and ground measurements.
Annual forest area change monitoring	**A national monitoring strategy needs to be developed** and the institutional capacity to undertake regular forest monitoring. Landsat and CBERS are available. Zambia has high percentage of dry tropical forest, phenological effects can therefore affect the image interpretation and have to be taken into account during the analysis; multi-temporal satellite data may be required. Forest fire is an important issue in Zambia, and the establishment of a **fire monitoring system is recommended**.
Carbon measurements	There is need to **install a continuous, systematic and standardized national inventory approach** to quantify above-/belowground biomass and soil carbon. Relevant governmental agencies need capacity building for biomass monitoring activities, carbon accounting and implementing measurement plots (an NFMA is currently in progress supported by FAO). Further steps: - Identification of national carbon stock key categories - Develop country specific sampling design and stratification - Implement field sample plots to derive the following parameters: o Allometric data (for biomass conversion and expansion) o Carbon fraction values considering country-specific stratification