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A SEVEN-COUNTRY ASSESSMENT OF NATIONAL CAPACITIES TO TRACK FOREST CARBON DIOXIDE EMISSIONS AND REMOVALS

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SUMMARY

Forest carbon monitoring is critical to evaluating whether policies aiming to reduce carbon dioxide emissions from forest change are achieving their goals. The objective of this brief is to highlight the technical capacity needs for implementing national systems for forest carbon monitoring. This paper assesses the technical capacity in seven countries—Brazil, Colombia, Ethiopia, India, Indonesia, South Africa, and Thailand—for monitoring forests, forest change, and associated carbon dioxide emissions and removals. The results can be used by national agencies and the international community, including donor agencies and non-governmental organizations, to identify priorities for capacity building and funding.

Based on findings from the assessment, the seven countries would benefit from the following:

- Establishing processes to regularly and more frequently update data to enable understanding of trends in forest change.
- Ensuring consistency of monitoring methods to allow comparison of data and interpretation of change over time.
- Improving spatial resolution of forest monitoring where important drivers of forest change are difficult to detect with mid-resolution satellite imagery.
- Establishing or updating national forest inventories regularly to enable accurate estimates of carbon dioxide emissions/removals.
- Developing protocols and training programs to guide and harmonize sub-national data collection.
- Strengthening data management and sharing among government agencies to enable integration of forest change information with other land use, permitting and tenure data.

INTRODUCTION

Spanning approximately 1.1 billion hectares (Achard et al. 2004), the world's tropical forests provide a rich reservoir of biodiversity and a wide range of ecosystem services including timber, fuel wood, water purification and regulation, erosion control, and cultural and religious values. In addition, the world's tropical forests help regulate the climate by storing 200 gigatons of carbon (Santilli et al. 2005), an ecosystem service of increasing importance as the impacts of human-induced climate change grow. The planet, however, is currently losing net 5.44 million hectares of tropical forest per year (Hansen et al. 2008). Deforestation and degradation of tropical forests account for approximately 12% of global carbon dioxide emissions annually (van der Werf et al. 2009).

Recognizing the importance of forests in the context of climate change, forested countries are developing policies aimed at improving the management of forests, reducing carbon dioxide emissions from forests (and enhancing removals of carbon dioxide from the atmosphere), and simultaneously achieving economic development goals. Evaluating the impacts of these policies requires robust information on a range of social, economic and environmental conditions both inside and outside forested land. A key first priority in supporting these policy goals is to develop and implement a forest carbon monitoring system that accurately measures carbon dioxide emissions and removals from forest cover change.

Monitoring can provide information on the extent and direction of forest change, where these changes are occurring, the nature of the drivers causing these changes, and whether greenhouse gas (GHG) emissions reduction targets have been reached. However, forest monitoring alone cannot directly attribute positive or negative trends in forest cover change as a result of implementing a specific policy. Forest cover change trends can also be affected by other factors, such as changes to the prices of crops that affect deforestation rates (Assunção, Gandour, and Rocha 2012). Additional information and analysis is needed to understand whether observed forest cover change is the result of a specific policy. However, a robust monitoring system provides critical input information, and is therefore a fundamental requirement, for policy tracking.

While a small number of developing countries have established forest carbon monitoring systems, most are still in development (Herold 2009; Romijn et al. 2012). Ongoing efforts to improve systems and capacities to monitor emissions from forest change at sub-national and national levels include those funded by the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD) and the World Bank's Forest Carbon Partnership Facility (FCPF). These efforts provide assistance to countries on preparation activities for the implementation of programs to Reduce Emissions from Deforestation and Forest Degradation (REDD+),[1] including the development of forest carbon monitoring systems.

Regardless of whether an international REDD+ system is established, forest carbon monitoring systems are necessary for tracking the effectiveness of domestic policies to mitigate GHG emissions and manage forests more sustainably. This brief supports these efforts by reviewing the technical capacities critical to building and maintaining a forest carbon monitoring system. 'Technical capacity' encompasses the infrastructure, technology, equipment and technical expertise to collect and analyze data that are in place for forest monitoring, as well as the processes and systems that enable information sharing. Additionally, this paper goes beyond recent studies that rely on internationally reported data by supplementing this with interviews from stakeholders on the ground.

This paper does not prescribe a specific pathway that each country should take to close existing capacity gaps. This will require evaluation by each country of its own specific needs and constraints, such as availability of financial resources, development priorities, and political motivation. Instead, this paper highlights the broad and fundamental technical capacity needs for forest carbon monitoring based on an assessment of current capacity gaps in seven countries.

ASSESSMENT METHODOLOGY

The authors developed a capacity assessment framework to systematically describe key technical capacity needs for forest carbon monitoring. This framework was informed by a review of literature on forest monitoring methods (Chasek et al. 2011; Defries et al. 2007; GOFC-GOLD 2010; IPCC 2006). The framework (Table 1) is designed to be comprehensive, yet flexible enough to be relevant to a wide range of country circumstances.

The framework was used to assess the technical capacity for forest carbon monitoring in Brazil, Colombia, Ethiopia, South Africa, India, Thailand and Indonesia. These countries were selected to represent a range of circumstances including geographic diversity, extent of forest cover and the importance of forest change to the greenhouse gas emissions profile of the country.

To complete each assessment, the study first collected background information for each country to better understand capacity needs relative to specific country circumstances. This included principal drivers of deforestation,[2] existing policies designed to reduce carbon dioxide emissions (or increase removals) from forests, and key agencies responsible for forest management and monitoring in each target country. Next, questions on capacity needs were answered using information derived from a combination of sources including literature reviews, surveys completed by in-country partners, and interviews with more than 50 national government and non-government experts.

Based on the assessment results, this paper identifies common technical capacity gaps, highlights best practices, and makes recommendations for funding priorities related to capacity building.

Forest carbon monitoring systems are necessary for tracking the effectiveness of domestic policies to mitigate GHG emissions and manage forests more sustainably.

TABLE 1

ASSESSMENT FRAMEWORK FOR EVALUATING TECHNICAL CAPACITY NEEDS FOR FOREST CARBON MONITORING

Background	Illustrative questions used for gathering background information in focus countries
Country context	• What is the extent of the country's forest cover? • Is forest change a major contributor to GHG emissions in the country? • What are the principal drivers of forest change and associated carbon dioxide emissions?
Policies and Institutions	• What are the existing policies related to mitigating carbon dioxide emissions from forest change and protection and management of forests? • Is there a designated agency responsible for monitoring carbon dioxide emissions from forest change?
Capacity Need	**Illustrative questions used for evaluating capacity in focus countries**
Forest change detection and carbon dioxide emissions quantification	• Is the country monitoring forest change at the national level? • What is the spatial resolution[a] of forest cover monitoring? Is the spatial resolution suitable to detect the important drivers of change? • What is the spatial extent of monitoring (i.e. national, regional)? • How often are data updated? • Does the country have a national forest inventory? Is it consistently measured and what is the frequency of conducting the inventory?
Sub-national monitoring standardization	• Are sub-national entities involved in forest data collection? • Do sub-national entities follow the same standards and protocols to consistently record measurements? • Is information collected by local and regional entities systematically sent to national-level forest monitoring agencies for aggregation of forest information? • Are there funding or capacity building efforts to encourage/enhance sub-national monitoring?
Data integration and management	• Is there a mechanism in place to store and share data between the national agencies responsible for forest monitoring and management? • Is information systematically and regularly updated to reflect the most currently available data? • Is data infrastructure and information technology sufficient to maintain and exchange data? • Is information on forest change integrated with spatial and technical data on land use management, including concessions, licenses, permits, and other contracts? • Is the information system centrally maintained and accessible to all internal users? • Is there a clear mechanism to link GHG emissions data to the decision making processes?

[a] Spatial resolution describes the level of detail that a remote sensing system can capture. High resolution data, such as those from Quickbird, show images down to 0.1 hectares, while medium resolution data, such as those from Landsat, capture images of 0.5 to 5 hectares (GOFC-GOLD 2010).

FINDINGS

The main findings of the assessments in each country are summarized in Table 2 and presented in more detail in Appendix 1.[3] The results demonstrate that while all of the countries have some of the requisite components of a comprehensive forest carbon monitoring system, all of them have key gaps. These results are consistent with the recent study by Romijn et al. (2012) demonstrating that 72 out of 99 tropical countries have large capacity gaps and only four countries—China, India, Myanmar, and Mexico—have both the forest cover monitoring and forest inventory capacity required for accurate estimation of carbon dioxide emissions from forest change.

Based on findings from the assessments in the seven countries, the following challenges are common in establishing or strengthening forest carbon monitoring systems:

1. **Lack of regular and frequent data collection and analysis:** Regular and frequent data collection and analysis enable nations to understand trends in forest change and associated drivers, and to develop appropriate policy responses in a timely manner. One-off, irregular, or infrequent monitoring events will not fully capture trends in forest change or enable policy interventions to address unintended forest conversion.

   The countries assessed show a wide range of monitoring frequencies. Ethiopia is not monitoring forest cover on a regular basis; the last national map was completed in 2005. Colombia and South Africa each completed three national forest cover maps since 1986 and 1996, respectively. Indonesia and Thailand produce maps every two to five years, and India and Brazil (only for the Amazon) produce maps every year or every two years.

2. **Inconsistent monitoring methods:** Inconsistencies in the methods used to estimate carbon dioxide emissions from forest change create difficulties when comparing results between years for any given country. This can distort policy tracking results because observed changes may be due to either policy impact or to variations in methodology. While remote sensing technology continues to improve, countries should prioritize consistency of data to prevent inaccurate comparisons of new and old records. When improvements are made to calculation or analysis methodologies, reprocessing or recalculating past data may be necessary to maintain data consistency.

   Of the countries assessed, only India and Brazil have established consistent methods for forest cover mapping. The governments of Colombia, Ethiopia, and South Africa rely heavily on research institutions and externally funded projects for data collection and analysis (Duffo et al. 2011; Echnoserve 2011; ERC 2011). These projects were conducted independently and the raw data and details of the method used often remain with the external entity and are not readily accessible to the public or government agencies. Thus, despite having national data for some years, government capacity on forest monitoring work remains limited in these three countries.

3. **Insufficient spatial resolution to detect important drivers:** To determine the efficacy of land use and forest mitigation policies, countries will need to develop monitoring systems that use data with spatial resolutions that are capable of detecting the drivers that policies are aiming to address. For example, small-scale forest degradation[4] due to selective logging or fuel wood collection cannot be detected using the same mid- or coarse resolution imagery that can be used to detect forest conversion (Table 3). This is significant, as tropical forests are logged at higher rates than they are cleared, and more than 400 million hectares of tropical forests are slated for timber production (Asner et al. 2009; Blaser et al. 2011; Putz et al. 2012).

TABLE 2

SUMMARY FINDINGS FROM ASSESSMENT OF CURRENT FOREST MONITORING CAPACITY[a]

(Please see page 21 for endnotes for this table.)

		Ethiopia	South Africa	Colombia
Country Background	**Forest cover,[b] (hectares, % of total country area, year measured)**	13 million, 11% (2005) (includes woodland in its calculation)	11 million, 9% (2000) (includes woodland in its calculation)	61 million, 53% (2001)
	Net forest GHG emissions/removals[c] (Gg CO_2e, % of national GHG emissions in year reported)	-9,876, -21% (1995)	-18,616, -0.05% (1994)	26,014, 14% (2004)
	Direct drivers of forest change[d]	Agricultural expansion, fuel wood consumption	Woodland timber exploitation through small-scale trade, commercial plantations, forest fires, fuel wood consumption[e]	Agricultural expansion, settlement, mining, illicit crops, infrastructure development, selective logging, forest fires
	Main forest monitoring agency	Forestry Research Centre	Department of Rural Development and Land Reform, Chief Directorate of Surveys and Mapping	Institute of Hydrology, Meteorology, and Environment Studies
Forest Cover Detection	**Spatial resolution[f]**	Mid-resolution (Landsat)[g]	Mid-resolution (Landsat)	Mid-resolution (Landsat)
	Mapping frequency	No regular mapping	Mapped forest cover in 1996, 2000, 2005	Mapped forest cover in 1986, 1996, and 2001
	Consistency of methods	Various externally funded mapping projects use different methods	Lacks consistency in data collection methods	Lacks consistency in data collection methods
Emissions Quantification	**National forest inventory**	Woody Biomass Project was completed in 2005; inventory work has ceased since	Incomplete; most extensive records are kept for plantations only	National forest inventory completed between 1990–1994 and 2000–2004 with high uncertainty rate
	Emissions factor [h,i]	IPCC-provided Default Values for different biomass in forest biomes (Tier 1)	IPCC-provided Default Values for different biomass in forest biomes (Tier 1)	IPCC-provided Default Values for different biomass in forest biomes (Tier 1)
Sub-national standards	**Sub-national level monitoring**	Some studies completed but on project basis	Some monitoring activities at state level, uncoordinated with federal agency	Some monitoring activities at regional level, lacking capacity and coordination
	Standardization of sub-national monitoring methods	None	None	None
Integration and Management	**Data management system**	No clear mechanism for data integration and management	Data are held by research institutions and are difficult to access by government officials	Forestry National Information System, part of the Environmental Information System of Colombia

Thailand	India	Brazil	Indonesia
19 million, 31% (2006)	68 million, 21% (2004)	520 million, 61% (2010)	101 million, 54% (2006)
-7,890, -3% (2000)	-67,800 -4% (2007)[j]	1,329,050 61% (2005)	1,125,828 63% (2005)[k]
Settlements, road construction, infrastructure development, forest fires, and agricultural expansion	Fuel wood consumption, timber plantations, encroachment, agricultural expansion, infrastructure development[l]	Commercial agriculture, settlement, infrastructure development, construction of new roads, small-scale farming, commercial and illegal logging, forest fires[m]	Commercial and illegal logging, large-scale commercial agriculture (i.e. oil palm), industrial plantations, forest fires, forest encroachment
Ministry of Natural Resources and the Environment	Ministry of Environment and Forests, Forest Survey of India and the National Remote Sensing Center	National Institute for Space Research	Ministry of Forestry
Mid-resolution (Landsat)	Mid-resolution (Landsat and others)	Mid-resolution (Landsat and others)	Mid-resolution (Landsat and others)
Irregular mapping by various agencies; started digital interpretation in 2000	Biennially	Multiple programs with mapping frequency ranging from 15 days to 1 year[n]	Every three years
Lacks consistency in data collection methods	Consistent since 1987	Consistent since 1988	Consistent since 2000
Conducted irregularly and by different agencies; overall, incomplete	National Forest Inventory designed and implemented in 2002; field inventories conducted biennially	In process of establishing updated inventory, to be published in 2014. Last National Forest Inventory (NFI) was completed in 1980s, but results were not achieved or published.	Last National Forest Inventory completed between 1986 to 1998
IPCC-provided Default Values for different biomass in forest biomes (Tier 1)	Emission Factors generated from country-specific forest inventory carbon data (Tier 2)	Emission Factors generated from country-specific forest inventory carbon data (Tier 2)	IPCC-provided Default Values for different biomass in forest biomes (Tier 1)
Some studies completed but on project basis	Indian Forest Service conducts surveying activities on the state level	Monitoring activities have been completed mostly independently	Local level monitoring projects have been completed mostly independently
None	Each state has its own training school to train foresters and forest guards	The new NFI has provided guidelines for data collection	None
No clear mechanism for data integration and management, statistical data is published online	National Natural Resources Management System (NNRMS) is an inter-agency system that integrates remote sensing data on natural resources	Ministry of Environment runs a database that integrates land use planning information involving nine sectors	Forest Monitoring and Assessment System (FOMAS) / Forest Resource Information System (FRIS) gathers geographic information on legal forest licenses and land use

TABLE 3

ABILITY OF MID-RESOLUTION SATELLITE IMAGERY TO DETECT A RANGE OF DRIVERS OF FOREST CHANGE (ADAPTED FROM PERES, BARLOW, AND LAURANCE 2006)

Easily Detected	Limited Detection	Nearly Undetectable
• Recent slash-and-burn agriculture • Major canopy fires • Major roads, settlements • Conversion to tree monocultures • Hydroelectric dams and other forms of flood disturbance • Large-scale mining	• Selective logging • Surface fires • Edge-effects • Old slash-and-burn agriculture • Small-scale mining • Unpaved secondary roads • Selective thinning of canopy trees	• Harvest of most non-timber plant products • Old selective logging • Small-scale selective logging • Narrow sub-canopy roads • Understory thinning and clear cutting • Fuel wood collection

The countries assessed show a wide variety of drivers of forest change, some of which require higher spatial resolution for detection, such as fuel wood collection and low-intensity selective logging. India, Ethiopia and South Africa cited fuel wood collection and Brazil, Indonesia and Colombia cited selective and illegal logging as drivers in their country strategies. These countries have established policies or shown initiative to address these drivers. However, all of the countries assessed used mid-resolution data that is insufficient to detect low-intensity selective logging and fuel wood collection to report to FAO's 2010 Forest Resource Assessment. Brazil and India are the only countries that currently have operational systems with the spatial resolution necessary to detect forest degradation which they use for domestic policy tracking purposes (see Box 1 and 2), though they do not use the data to report to the FAO.

4. **Lack of complete and regularly updated forest inventories**: Regularly updated national forest inventories are essential to the development of country-specific emission factors, which are used to estimate carbon dioxide emissions from forest change.[5] Current operational remote sensing methods have limited ability to quantify forest biomass.[6] Thus, forest inventories provide information on the amount of biomass per unit of forest area in a range of forest strata and management types.

   Of the countries examined, Brazil and India are the only ones using Tier 2 emission factors to estimate forest carbon stock; all the other countries are using Tier 1 IPCC default values. Brazil has completed only one national forest inventory, but is in the process of establishing a forest inventory that will be regularly updated. Colombia completed two national forest inventories, but with high rates of uncertainty. Indonesia lacks an updated national forest inventory; the last inventory was completed in the 1990s and took more than a decade to complete.

5. **Lack of sub-national monitoring standardization:** Sub-national monitoring is the direct involvement of sub-national entities in monitoring, for example by decentralizing monitoring responsibilities to the state level and by training and contracting local workers to carry out data collection tasks. Particularly in cases where forest cover changes are difficult to detect with satellite imagery, such as forest degradation or enhancement of carbon stocks, direct field observations are often the only way to collect data on emissions and track policy impacts.[7] However, for sub-national monitoring to be effective, national standards and protocols need to be provided to sub-national entities and adhered to in order to ensure quality and consistency. This would require capacity building to provide state and local forest officials with procedural information and, where necessary, the technical skills and resources needed to meet the national standards.

BOX 1

BRAZIL'S FOREST MONITORING SYSTEM

Brazil's National Institute for Space Research (INPE) was formed in 1971 and runs a number of programs dedicated to forest monitoring:

- **Monitoring of the Brazilian Amazon Forest (PRODES)—**PRODES processes Landsat (along with CBERS and DMC data, two other satellite imagery sources) on a yearly cycle, generating information on clear cutting activities in the Amazon every 12 months (May and Millikan 2010). This information is used for carbon accounting, using IPCC default values, and year-to-year comparison of forest area lost to clear cutting. In 2010, PRODES began reporting accuracy assessments and generating products using a minimum mapping unit (MMU) of 1 hectare in addition to continuing the existing time-series at a MMU of 6.25 hectares to maintain consistency (Norad 2011a).
- **Real-Time Detection of Deforestation (DETER)—**DETER was developed in 2004 and provides near real-time detection of deforestation larger than 25 hectares every 15 days. DETER provides results to the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) biweekly to notify forest law enforcement officials where illegal deforestation is detected. As a result of the availability of this information, IBAMA has successfully shut down 100 illegal operations in the Amazon (Norad 2011a).
- **Mapping Forest Degradation in the Brazilian Amazon (DEGRAD)—**DEGRAD is a program set up to specifically target forest degradation. DEGRAD uses Landsat and CBERS data at the minimum mapping unit of 6.25 hectares and image processing techniques developed by INPE to detect forest degradation. Results are published yearly for the previous year and have so far shown indication of increasing degradation in the Legal Amazon (Norad 2011a).

Thus far the policies, and thus monitoring priorities, have focused on the Amazon and to a lesser extent the Cerrado. Trends outside of these areas are less understood and more work will need to be done to increase accuracy and data availability there.

India is the only country of the seven assessed that has state-level monitoring coordinated at the national level. Brazil is in the process of establishing a regularly updated National Forest Inventory and, for this purpose, has provided guidelines for state-level data collection. Prior to this, however, some states in Brazil have been developing their own forest inventories independently and without coordination of methodologies and timing with other states and the federal government. Indonesia, South Africa, Thailand, and Ethiopia, and Colombia have some monitoring activities on the sub-national level, but these are conducted independently and without guidance from the federal level to facilitate data aggregation.

6. **Lack of data management and integration:** Integration of information on current forest cover, forest management, and legal status of forest use is vital to effective tracking of policy impacts. Forest change information that is not paired with reliable tenure, land use, and permitting data could be misinterpreted. For example, without information on management permits, legal forest change could be interpreted as illegal, or vice versa. To enable this integration of data, coordination between and input from relevant agencies, and a reliable and frequently updated data management system is needed. This data management system should receive and maintain data from all forest-relevant agencies and make data publically available.

Ethiopia, South Africa, and Thailand currently do not have a system for managing and integrating forest-related data from various agencies involved in forestry work. For instance, in Thailand, responsibility for forest regulation and monitoring is dispersed across a number of institutions, and there is a lack of a central agency mandated to collect and integrate data from various agencies (TGO 2012). India, Brazil, Indonesia, and Colombia have some form of data management system in place, but important information for informing appropriate policy actions is missing from the system. For example, Brazil is in the process of integrating forest cover data with spatial information on public and private ownership of forest land.

BOX 2

FOREST SURVEY OF INDIA

India began national forest cover mapping using remote sensing technology in the 1980s and has steadily made advancements in its forest monitoring technology and methods. Since 1984, the Forest Survey of India has been conducting regular forest cover assessments and releasing a "State Forest Report" on a biennial basis. In 2000, India began digitally interpreting data collected from its own high-resolution satellite, supplemented with ground verification and accuracy assessment. Maps are produced on a 1:50,000 scale and characterize forest cover at 1 hectare scale. Important forest changes, including increases in forest cover due to reforestation can be detected. India's current National Forestry Inventory (NFI) has been in use since 2002 and updated biennially. The NFI uses a sampling method that measures 8000 sample plots on a two-year cycle to estimate the country's growing stock (Aggarwal, Das, and Varghese 2009).

RECOMMENDATIONS

We propose the following actions to help the assessed countries and other developing nations address the challenges in establishing or strengthening forest carbon monitoring systems:

1. **Establish regular data collection:** National and sub-national agencies responsible for forest monitoring should analyze and update data at least every two years to enable understanding of trends in forest change, tracking of policy effectiveness, as well as timely determination of appropriate policy interventions.

2. **Use consistent monitoring methodologies:** Forest monitoring agencies should use consistent methods over time to allow accurate comparison of data and interpretation of change detection. Countries should prioritize in-house capacity building to enhance the government agency's ability to maintain consistency over time.

3. **Ensure sufficient spatial resolution:** Countries should use satellite-based monitoring systems with a spatial resolution capable of detecting important drivers of forest change, particularly if the country wants to track progress towards reducing the impact of those drivers.

4. **Conduct systematic regular forest inventories:** The agencies responsible for forest monitoring should conduct national forest inventories, at least every five years, to develop accurate emission factors for the estimation of carbon stock and to supplement remotely sensed data. This would require funding for increasing the number of trained staff and the availability of equipment for data collection and analysis.

5. **Standardize sub-national data collection:** Forest monitoring agencies should develop protocols and standards to guide and harmonize sub-national data collection to enable aggregation of data, and mandates to sub-national entities to collect this information. Additionally, sub-national entities should be supported with technical training and equipment to adhere to protocols and standards guiding data collection.

6. **Establish data integration and management systems:** Entities monitoring forest change should work with other government agencies to integrate forest change, land use, permitting, and tenure data. This will enable accurate interpretation of forest cover change detection and determination of appropriate response action. One way to do this is to set up a data integration and management system to allow various ministries with different responsibilities affecting forest cover to share information and make data widely available. This may require a supra-ministerial entity that can coordinate such a data management system.

BOX 3

USING THE FOREST CARBON MONITORING SYSTEM FOR POLICY TRACKING

Tracking the impacts of policies aimed at reducing emissions from forest change is a multi-step process that includes the tracking of policy implementation, the establishment of baseline scenarios, the development of metrics of success, and the evaluation of indicators signaling whether progress has been made. Such a system enables evaluators to determine whether a policy has been implemented and enforced, whether the policy has been successful in reaching its goals, and where improvements can be made.

The data generated from forest monitoring are critical inputs to any policy tracking system that aims to measure impacts of policies in the forest sector. However, forest monitoring will only be useful for policy evaluation if the data are communicated and delivered in a way that can be incorporated into a policy tracking system. Furthermore, policy tracking is an iterative process, in which up-to-date forest change information is used consistently over time in the repeated evaluation of performance.

Hence, agencies responsible for data collection and analysis should make information easily accessible and transparent to enable the evaluation of policy performance, and to inform decisions regarding policy implementation. More information about policy tracking can be found in Kusek and Rist (2004) and FAO (2006). The World Resources Institute's Open Climate Network (http://insights.wri.org/open-climate-network/) is also working on developing policy assessment tools, which will be made available to the public soon.

Achieving a robust and comprehensive monitoring system would require the allocation of more funds by the government, and the financial and technical assistance of bilateral and multilateral partnerships.

CONCLUSION

All the countries assessed have plans for improving their forest carbon monitoring systems and are expected to receive or dedicate more funding to making these improvements in the near future. Given limited capacity and financial resources, they will need to decide which capacity gaps to prioritize and where investment would be most cost-efficient. This prioritization should be based on country-specific drivers of forest changes and the policy interventions that countries choose to implement and track. A phased approach, where monitoring systems with lower accuracy but also lower costs are implemented first and gradual enhancements are made, may be more practical in the near term. Regardless of the approach, achieving a robust and comprehensive monitoring system that embodies the recommendations presented above would require the allocation of more funds by the government, and the financial and technical assistance of bilateral and multilateral partnerships.

This paper provides a snapshot in time of the current forest carbon monitoring systems in seven countries. Each of the seven countries assessed was found to have key technical capacity gaps relating to standardization, consistency, and data integration and management. Given the high stakes associated with forest protection for reasons such as sustaining ecosystem services, supporting livelihoods, and mitigating climate change, these countries should strengthen the technical capacity of their existing forest carbon monitoring systems to track forest policy performance and ensure policy goals are met.

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APPENDIX: SUMMARY OF CAPACITY ASSESSMENT BY COUNTRY

BRAZIL

Background	Brazil has the highest tropical forest cover in the world, with 520 million hectares of forest land, making up 61% of its total area in 2010 (FAO 2010a). The main drivers of deforestation are cattle ranching, commercial agriculture, particularly soya bean cultivation, illegal logging, large-scale infrastructure, construction of new roads, and small-scale farming (Norad 2011a). Brazil's main forest monitoring agency is the National Institute for Space Research (INPE) and the main forest policy development agencies are the Ministry of the Environment, the Brazilian Forest Service, the Brazilian Institute of Environment and Renewable Natural Resources, and the Chico Mendes Institute of Biodiversity Conservation. Brazil has a number of policies aiming to fight deforestation and increase sustainable use of forest resources. In 2004, the Action Plan for the Prevention and Control of Deforestation in the Amazon Region (PPCDAM) was implemented to establish land tenure and classification and improve monitoring capacity and enforcement of forest laws. The Action Plan also expanded the amount of forest classified as federal protected areas across the Amazon. In addition, Brazil has also imposed a moratorium on soybean growth on newly deforested land since 2006, committed to GHG emissions reductions by 36-39 percent below business-as-usual levels (2005 as base year) by 2020, and developed a Plan for Prevention and Control of Deforestation and Forest Fires in Cerrado (PPCerrado) in 2010.
Forest change detection and emissions quantification	Brazil's forest cover monitoring using remote sensing and GIS technology is very advanced. INPE produces yearly forest cover maps that show deforestation activities in the Amazon over 12 months, using LANDSAT, CBERS, and DMC data. Additionally, INPE has also developed a near real-time deforestation detection program (DETER) and a forest degradation detection program (DEGRAD), both using a minimum mapping unit of 6.25 hectares (See Box 2). INPE also developed the Detex system in 2007, which detects selective logging in forest concessions. However, most monitoring activities have been focused on the Legal Amazon and monitoring of areas outside of the Legal Amazon, like the Atlantic Rainforest, has been limited. While Brazil's forest cover change detection is highly advanced, its emissions quantification activities have been limited. Brazil has only completed one national forest inventory since the 1980s, and additional forest inventories thereafter have been conducted on the regional level. The Brazil Forest Service is now in the process of establishing a regularly updated National Forest Inventory (5-year measurement cycle) to provide up-to-date and reliable emissions factor information.
Sub-national standardization	Some States have their own forest inventories, but these activities have been completed independently and without coordination with other states in methodologies and timing (de Freitas et al. 2009). The new Brazilian National Forest Inventory (NFI) in progress has established committees for technical consultations at the national and state levels. Specific guidelines have been provided to guide data collection of sample clusters, such as quantitative and qualitative forest attributes, species identification, and socioeconomic surveys of nearby local communities. An NFI field manual is available that provides vegetation measurement protocols for different biomes. Furthermore, the Brazilian Forest Service has also established a Training Program and Quality Control Program to improve human resource capacity to meet data quality standards and develop procedures for data quality control (de Freitas et al. 2009). Capacity for forest inventories is sufficient at the national level, but additional capacity may be required at the sub-national level.
Data integration and management	The Ministry of Environment (MoE) coordinates land use planning between states and between sectors. MoE developed a universal database, in collaboration with the Technology Management and Innovation Center (CTGI), to integrate all state level databases and land use planning and zoning information. Nine different sectors are included: agribusiness, family based agriculture, logging, mining, industry, tourism, non-timber forest products/biotechnology, extractive activities and indigenous people. Additionally, the Land Use Planning Brazil Consortium coordinates environmental and socioeconomic information produced by thirteen institutions and used in the land use planning process. This consortium promotes communication between agencies and cooperation between the federal government and the state governments to assist them in the development of state level land use plans. While plans to aggregate information on land tenure from different agencies were included in the federal law 102671/2001, there is currently no central database with accurate spatial information available on private and public forest ownership.

APPENDIX: SUMMARY OF CAPACITY ASSESSMENT BY COUNTRY

COLOMBIA

Background	Native forests covered 53 percent of Colombia in 2001 (FAO 2010b). Drivers of deforestation include expansion of agriculture, small-scale farming, mining and infrastructure development, illicit crops, illegal logging, fuel wood consumption, forest fires, and selective logging. The Ministry of Environment and Sustainable Development (MADS) is the main agency responsible for managing environmental and natural resource policies, including REDD+ policy development and communication with international institutions. The Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) and the National Environmental System (SINA) are responsible for gathering and managing scientific and technical information on ecosystems used in the classification and zoning of land use. IDEAM is also responsible for providing information on national forest cover and preparing national communications to the United Nations Convention on Climate Change (UNFCCC) (Government of Colombia 2011). Colombia's National Forestry Development Plan was developed in 2000 and established programs focusing on zoning, ecosystem restoration, reforestation, and others to help improve forest management practices. Despite this, environmental management remained in the background until 2010, when the National Development Plan 2010-2014 visibly factored in environmental concerns and established new environmental policy goals. The plan also called for the development and implementation of a national strategy for REDD+. In addition, Law 139 of 1994 established the Forestry Incentive Certificate program, which awards payments for forest restoration efforts for select species. This system, however, has yet to be implemented, but continues to be mentioned as a viable instrument for increasing forest cover.
Forest change detection and emissions quantification	Colombia mapped forest cover in 1986, 1996, and 2001 and published results in 2004. One of IDEAM's key capacity gaps is the lack of standard data collection procedures. GHG inventory development activities by independent parties use different methodologies, making comparison of data between different years difficult. Furthermore, data collection and analysis has been completed mainly by universities and non-government institutions (Government of Colombia 2011), indicating the lack of permanent country capacity to sustain data collection activities. This is mainly due to insufficient allocation of funds to retain well-qualified professionals and sustain monitoring capacity (Andres Duffo, pers. comm.). Currently, estimates of carbon stock in natural forests are derived from data collected from temporary and permanent survey plots laid out over twenty years (1990-2010). Two national forest inventories have been completed between 1990-1994 and 2000-2004. However, the estimates of carbon dioxide emissions have high levels of uncertainty due to poor quality of information used and lack of adequate training of government personnel in the calculation of emissions (Government of Colombia 2011).
Sub-national standardization	At the regional level, technical capacity is low due to budget constraints. Information systems and basic maps of the Autonomous Regional Corporations' (CARs) jurisdictions are lacking or outdated. Law 99 of 1993 devolved the responsibility of implementing national policies and establishing data management systems to the CARs, which are fiscally and politically independent of the national government. This autonomy discourages coordination between regional and national governments. Furthermore, there is no coordination in method of data analysis and integration of regionally collected information with IDEAM data (Blackman, Morgenstern, and Topping 2006). Poor division of responsibilities between national and sub-national entities is a major limitation that would hinder the successful implementation of a REDD+ strategy (Gutman and Patterson 2010).
Data integration and management	IDEAM runs the Environmental Information System of Colombia (SIAC), which is composed of a number of information systems for different sectors and provides data for the national GHG inventory. One of these information systems is the National Forest Information System that handles and disseminates information on forests and forest and land cover types to inform decisions on forest management (Duffo et al 2011).

APPENDIX: SUMMARY OF CAPACITY ASSESSMENT BY COUNTRY

ETHIOPIA

Background	Ethiopia's forest cover (including forests, high woodland areas, and plantations) was 11 percent of its total land area in 2005, with an additional 42 percent of low woodlands and shrublands (FAO 2010c). The main drivers of deforestation are expansion of agriculture, settlement, wild fires, and lack of regulation to curtail an "open access" mentality (Government of Ethiopia 2011). The major driver of forest degradation is fuel wood consumption; fuel wood supplies 94 percent of total household energy consumption (Echnoserve 2011). Ethiopia currently does not have a national-level institution dedicated to forestry. The Environmental Protection Authority (EPA) is the main agency responsible for forest regulation in Ethiopia and the Ministry of Agriculture is in charge of REDD+ and afforestation/reforestation projects. However, Ethiopia recognizes deforestation as a major concern that affects other important resources, such as agriculture, animal husbandry and water resources, and has increased efforts to protect forests. Ethiopia has been completing preparation work for REDD+ and has recently submitted its 'Readiness Preparation Proposal' to FCPF. Ethiopia has also completed the Green Economy segment of the Climate Resilient Green Economy Strategy in 2011, and is now completing the climate resilience segment dedicated to adaptation. The goal of the CRGE Strategy is to develop sustainably and achieve carbon neutrality by 2025 through adaptation and mitigation activities in seven sectors, one of which is forestry/REDD+.
Forest change detection and emissions quantification	There are some estimates of forest cover and emissions in Ethiopia produced from national and sub-national mapping projects, but these are one-time, externally funded projects and are not carried out consistently over time. The most comprehensive and reliable forest inventory project in Ethiopia, the Woody Biomass Inventory and Planning Project (WBISPP), was carried out between 1989 and 2005. The project increased understanding of consumption patterns of woody biomass and impacts of fuel wood removal on land cover change (WBISPP 2004). A comprehensive and consistent monitoring system is included in Ethiopia's REDD+ readiness strategy. Its goal is to develop reference scenarios and country-specific emissions estimates by 2015 (Government of Ethiopia 2011). The planned monitoring system, which will be based on mid-resolution Landsat data with change detection once every five years, may be useful for detecting some important drivers, including settlement, and large-scale agriculture.
Sub-national standardization	Sub-national entities have not been regularly involved in data collection for GHG emissions accounting due to lack of financial and technical resources and skilled personnel. The Woody Biomass Inventory and Planning Project included a capacity building component and provided training to involve more local officials in data collection. However, technical capacity was not built sufficiently for forestry staff to replicate the process after the end of the project without external support. Thus, sub-national technical capacity remains low.
Data integration and management	Responsibilities for managing and monitoring forests are dispersed to multiple agencies, including the EPA, the Natural Resources Conservation and Development Department of the Ministry of Agriculture, and the Wildlife Conservation Authority within the Ministry of Culture and Tourism. The Forestry Research Center also collects data, but has limited data management capacity. Interviews with officials from these agencies indicate that coordination has been difficult and responsibilities have been unclear due to the lack of a central agency responsible for data collection and management (Echnoserve 2011). In January 2012, the government established that REDD+ implementation is to be handled by the Ministry of Agriculture while regulatory and monitoring functions are retained by the Environmental Protection Authority.

APPENDIX: SUMMARY OF CAPACITY ASSESSMENT BY COUNTRY

INDIA

Background	India had 68 million hectares of forests in 2004, making up 21 percent of total country area (FAO 2010d). Drivers of deforestation and degradation include excessive harvesting of timber and fodder, encroachments, shifting cultivation, forest fires, diversion of forests for development, and fuel wood consumption by households for domestic cooking and by unorganized small- and medium-sized enterprises. The Indian government has implemented drastic reforestation/afforestation programs since the 1980s. Between 1980 and 2005, a cumulative area of about 34m hectares of forest plantation was established. The Joint Forest Management program, which enlists the participation of local communities, helped reforest about 15m hectares of land (UNFCCC 2007). Reforestation is also a large part of the Green India Mission (2011-2022) under the National Action Plan on Climate Change (NAPCC). The Green India Mission aims to double the area designated for afforestation and eco-restoration in order to reach the goal of increasing carbon dioxide removals by forests to 6.35 percent of total GHG emissions by 2020. Key institutions include The Ministry of Environment and Forests (MoEF), the Indian Forest Service, and the Environment and Forests Division of the National Informatics Centre. The Indian Council of Forestry Research and Education (ICFRE), the Forest Survey of India, and the National Remote Sensing Center are principally responsible for forest emissions monitoring and quantification.
Forest change detection and emissions quantification	India has been conducting forest cover assessments on a biennial cycle using digital interpretation of satellite data since 1987 and has completed eleven cycles of forest cover mapping. This assessment is supplemented with intensive ground-truthing and accuracy assessment. India has its own satellite sensors capable of providing high resolution mapping. The Forest Survey of India began an inventory of growing stock in 1965, surveying 80 percent of the country's forests. In 2002, they developed and adopted a new National Forest Inventory that generates a new estimate of national growing stock every two years (Aggarwal, Das, and Varghese 2009). India releases a "State of the Forest" report every two years with great detail of procedures, system specifications, and accuracy assessments for the assessment of the country's forest cover, mangrove cover, and growing stock (e.g. biomass which translates easily to carbon). The latest report was released in 2011.
Sub-national standardization	The Indian Forest Service (IFS) is highly structured and well-trained on every level of forest surveying activities. In addition to the main training school, Indira Gandhi National Forest Academy, each state has its own training school to train foresters and forest guards (FAO 2009a). Additionally, the National Remote Sensing Center has a Training Division that provides training to professionals and scientists on remote sensing and GIS.
Data integration and management	India's National Natural Resources Management System (NNRMS) is an inter-agency system for integration of remote sensing data to build an inventory of information for improved decision-making and natural resource management. The NNRMS framework is made up of nine standing committees: Agriculture & Soils, Bio-resources, Cartography & Mapping, Geology & Mineral Resources, Ocean & Meteorology, Rural Development, Training & Technology, Urban Development, and Water Resources. The Bio-resources committee is composed of the MoEF, the Planning Commission, Department of Agriculture and Cooperation, state-level Department of Forests, the Forest Survey of India, and others.

APPENDIX: SUMMARY OF CAPACITY ASSESSMENT BY COUNTRY

INDONESIA

Background	Indonesia's forest cover made up 54 percent of its total land area in 2006 (FAO 2010e). Deforestation accounted for 83 percent of Indonesia's total emissions between 1990 and 2000 (WRI 2007). Around 33.4 million hectares of land are considered degraded forest area (FAO 2009b). The main drivers of deforestation and degradation are commercial and illegal logging, large-scale commercial agriculture, industrial plantations, and subsistence agriculture. The Ministry of Forestry (MoF) is the main agency in charge of managing and monitoring of the Indonesia's forest estate. Within the Ministry, responsibilities are dispersed to the Directorate General of Forestry Planning, Center for Forestry Planning and Statistics, and the Forest Research and Development Agency. Additionally, the Ministry of Agriculture and local governments have jurisdiction over land designated for production. MoF's Climate Change Sectoral Road Map outlines strategies to reduce emissions from the forestry sector, including increasing sustainable forest management, reducing emissions through improved management of forest conversion and REDD+, and increasing use of non-forest lands for plantations. In May 2010, Norway signed an agreement with Indonesia to support REDD activities, including development of national strategy and MRV institution, capacity building, legal reform for improved governance, and creation of a degraded land database (Austin, Stolle, and Gingold 2010).
Forest change detection and emissions quantification	Wall-to-wall mapping of land cover is conducted every three years using medium resolution images (FAO 2010e). However, accuracy of assessments has been limited by issues with cloud cover. Many ongoing projects have been working on capacity building in forest cover monitoring. However, data availability and technical capacity for monitoring forest degradation is very limited and requires more attention. Indonesia has limited carbon stock information needed for emissions quantification. For FAO's Forest Resource Assessment 2010, Indonesia used default conversion factors provided by IPCC guidelines (Tier 1) to estimate carbon stock, which yields estimates with high uncertainty. Indonesia has the capacity to use Tier 2 emissions factors (using country-specific information rather than default conversion factors) to estimate carbon stock and emissions (Norad 2011b), but a national level system of measurement is needed.
Sub-national standardization	Since 2007, local level REDD projects have produced more accurate forest carbon stock estimates by providing more site-specific carbon pool data (Norad 2011b). These efforts are largely independent and were collected using varying methodologies.
Data integration and management	Beginning in 2006, Indonesia's FOMAS system integrated up-to-date information on forest resources, including geographic information on legal forest licenses of forest concessions and plantations and forest change data. In addition, FOMAS established a data sharing protocol and disclosure policy to help improve decision-making. Indonesia is now building upon FOMAS in the new Forest Resource Information System (FRIS), which aims to expand forest monitoring capacity and include information on agriculture and land use (Norad 2011b). The country is also putting in place the OneMap program, which will verify, consolidate and standardize spatial information from multiple agencies.

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SOUTH AFRICA

Background

South Africa's forest cover was 9 percent of its total land area in 2000, made up of forests, woodlands, shrublands, and plantations (FAO 2010f). Current drivers of deforestation and degradation include fuel wood consumption, settlement, and forest fires.

The Department of Agriculture, Forestry and Fisheries (DAFF) is responsible for developing and implementing forest policies. The Chief Directorate of Surveys and Mapping under the Department of Rural Development and Land Reform is responsible for mapping land cover and use of the country. Forest policies are low on South Africa's list of priorities for mitigation of GHG emissions, since forest cover is low and forestry is a net sink. The objectives of forest policies in the past two decades have shifted from enhancing timber production to sustainable forest management. These objectives were laid out in the White Paper on Sustainable Forest Development of 1996, which established the goals of placing forests under state protection, forest fire prevention, developing forest inventories, implementing certification of productions, and other environmental protection measures. Additionally, South Africa's Forestry 2030 Roadmap (strategy for 2009-2030) aims to increase afforestation and forest rehabilitation projects.

Forest change detection and emissions quantification

Forest monitoring and data availability in South Africa has been limited by the low priority of the forest sector in the country. Monitoring has been traditionally used to describe the extent of various forest types, but has not measured biomass in many forest types. Some work has been done in the Thicket biome because of its high sequestration potential (Sebataolo Rahlao, Pers. Comm.). Time lags in collected and updated data have been significant. A national land-cover mapping was completed using data from 1994, 2000, and 2005. However, the map for 2000 was published in 2005 and each mapping project incorporated different sources of information (Schoeman et al. 2010), creating more accurate but incompatible maps. The most consistent forest data available are plantation data collected since the 1970s (DEA 2010).

There is currently no national data on forest carbon stock. According to South Africa's FAO Forest Resource Assessment (2010e), the country expects to establish field inventory and forest cover mapping using remote sensing in 2012. A national working group has been formed and is now working on accumulating this data, primarily for the national GHG inventory.

Sub-national standardization

While the National Forests Act provides a framework for reporting at the national level, this framework has yet to be adhered to in collection and organization of data at the local level. For the 2005 mapping of land cover, finer scale data collected by some provinces and municipalities were incorporated, indicating that there is some technical capacity on the sub-national level for data collection. However, this is limited to some provinces and municipalities, hence requiring the project to utilize outdated information to fill in data gaps. More national-level guidance is needed for improved sub-national data collection and technical capacity to increase accuracy and consistency of land cover data and mapping.

Data integration and management

A number of research institutes, including the Agricultural Research Council (ARC), the Council for Scientific and Industrial Research (CSIR), Wits University's Climatology Research Group and the Energy Research Centre, have been commissioned to collect forest data, due to the lack of capacity within government agencies in the forest sector. These data, however, have remained with the research institutes and have not been transferred or made readily available to government agencies (ERC 2011).

In 2011, the DEA and DAFF formed a working group dedicated to measuring emissions from AFOLU to contribute to the national GHG inventory and MRV. This working group consists of the ARC, CSIR, Wits University, University of Cape Town's Energy Research Centre (ERC), and the Climatology Research Group (CRG) (ERC 2011).

APPENDIX: SUMMARY OF CAPACITY ASSESSMENT BY COUNTRY

THAILAND

Background	In 2006, Thailand had 16 million hectares of forest, making up 31 percent of the country (FAO 2010g). Thailand imposed a commercial logging ban in 1989 and subsequently designated natural forest areas as protected areas. The main drivers of deforestation and forest degradation are conversion to agriculture and other land uses, settlement, fuel wood consumption, and forest fires. A number of agencies are involved in forest management and monitoring. The Ministry of Natural Resources and the Environment (MoNRE) is responsible for forest management and is made up of a number of divisions with various forest-related duties. Within MoNRE, the Department of National Park, Wildlife and Plant Conservation (DNP) is responsible for protected areas and degraded forests, while the Royal Forest Department (RFD) controls forest areas outside of designated protected areas. The Thailand National Remote Sensing Center and Geo-Informatics and Space Technology Development Agency (GISTDA) manages remote sensing data, conducts research on remote sensing technology and GIS, and controls Thailand's satellite. However, there is no agency directly responsible for measuring emissions from forest change (TGO 2012). Thailand aims to increase the national forest cover to 40 percent by 2020. The 10th National Economic and Social Development Plan (2007-2011) sets a target of maintaining at least 33 percent of the total area under good forest cover, of which 18 percent should be protected area; the target for restoration of protected areas is set at 464,000 hectares. Thailand has developed a 4-year Implementation Plan (2008-2011) to address deforestation and degradation through a hotline center for illegal logging and forest fires, improved enforcement, and local community participation.
Forest change detection and emissions quantification	DNP and RFD both contribute to forest cover monitoring and the national forest inventory. Forest cover maps are updated irregularly and different agencies generate data using different methods (TGO 2012). Thailand launched its own satellite, the Thailand Earth Observation Satellite (THEOS) in 2008. However, the country needs to develop conversion factors for species other than commercial species and improve ground-truthing methods to increase representative sampling. Additionally, data on forest degradation is lacking and a systematic monitoring method for forest degradation needs to be developed.
Sub-national standardization	Currently, carbon dioxide emissions from forest and land use change are not measured on the sub-national level (TGO 2012). Technical capacity building and training programs, including development of standards for data collection and analysis, are needed for data collection on the sub-national level.
Data integration and management	Coordination between the many agencies involved in forest management is insufficient. Data management is difficult due to the incomparability of data collected by different agencies. Forest-relevant spatial data, such as road network, forest protected boundaries, land suitability for crop types, and land use zoning, is made available for informing management decisions. However, carbon dioxide emissions data has not been used for land use planning and forest management (TGO 2012).

ENDNOTES

1 The "+" in REDD+ refers to additional activities including sustainable management of forests, conservation of forest carbon stocks and enhancement of carbon stocks.

2 Drivers of forest change are either proximate causes, which are actions that have an immediate or direct impact on forest cover, or underlying causes, which are driving forces that emerge from social processes and create indirect impacts (Geist and Lambin 2002). Examples of direct drivers of forest change are agricultural expansion, illegal logging and fuel wood collection. Indirect drivers include population growth, adverse forest and agriculture policies, and poor law enforcement.

3 This study was conducted as part of the World Resources Institute's Measurement and Performance Tracking project, an initiative that helps countries build capacity to track performance of policies that aim to reduce GHG emissions while achieving development goals. Scoping of capacity gaps in six target countries were completed in 2011. The scoping reports can be accessed at https://sites.google.com/site/maptpartnerresearch/.

4 Degradation, though challenging to quantify, is estimated to affect about 2.3 million hectares of forest a year globally in the tropics (Achard et al. 2004). Degradation due to selective logging can be detected by mid-resolution imagery where effects are periodic and highly localized (Souza, Dar, and Andre 2005), and effects on biomass can be quantified (Asner et al. 2004). However, more subtle and incremental degradation, such as that caused by low intensity selective logging and fuel wood collection, requires more costly high resolution data, supplemented with extensive ground-truthing, for accurate detection (DeFries et al. 2007; Skutsch 2004).

5 There are two primary data requirements for estimating carbon dioxide emissions from forest change- the activity data, or the area that has undergone change, and the emissions factor, which is the amount of carbon dioxide emissions/removals per unit area (IPCC 2006). The use of remote sensing techniques supplemented with ground verification is considered the most consistent, cost-effective and accurate method of obtaining forest cover change data (activity data) and is becoming increasingly accessible to developing countries (Defries and Townshend 1999; Fuller 2006; Rogan and Chen 2004). National forest inventories, which provide site-specific information on factors that affect carbon stock, such as species, diameter, height and age of trees, are needed to determine the emissions factor.

6 Non-optical remote sensing methods, such as LiDAR (Light detection and ranging) and RADAR (radio detection and ranging), are making progress toward the monitoring of forest parameters that can be used to estimate forest biomass. However, the majority of countries these methods are still in the research phase.

7 Recent studies have demonstrated that for direct field observations, community forest emissions monitoring can be as accurate as professional monitoring (Skutsch 2004). Additionally, new technologies, such as Global Positioning System (GPS) and smartphone technology, can make sub-national monitoring even more accurate and efficient.

ENDNOTES FOR TABLE 2

a Information was gathered from national policy documents, scoping reports from in-country partners and a number of country-submitted reports, including REDD Readiness Preparation Proposals (R-PP), REDD Readiness Plan Idea Note (R-PIN), National Communications to the UNFCCC, and Food and Agriculture Organization's (FAO) 2010 Forest Resource Assessment. Due to variations in figures presented in different sources, the figures for forest cover and spatial resolution were taken from a single source to maintain consistency.

b As reported in the Food and Agriculture Organization (FAO) 2010 Country Reports. The figures presented include plantations.

c Latest year reported to the UNFCCC, unless otherwise noted.

d As specified in country's REDD Readiness Preparation Proposals (R-PPs) submitted to the World Bank's Forest Carbon Partnership, unless otherwise noted.

e As specified in South Africa's Forestry 2030 Roadmap (Forestry Strategy 2009-2030).

f Used for reporting to the FAO 2010 Forest Resource Assessment Country Report.

g Landsat satellites acquire mid-resolution images. Landsat data is free and is managed by NASA and the U.S. Geological Survey. More information is available at http://landsat.gsfc.nasa.gov/.

h Used for reporting to the FAO 2010 Forest Resource Assessment Country Report

i The Intergovernmental Panel on Climate Change (IPCC) has classified emission factors into three tiers. IPCC-provided default emission factors (Tier 1) are estimates of carbon stock for various types of forest and are not country-specific, thus introducing a large error range in calculation of emissions. Tier 2 is an improvement and involves the use of updated country-specific data. Tier 3 is the ideal approach, where estimates of carbon stock are based on repeated measurements of forest biomass and modeling of emissions to continually improve the accuracy of emission factors (GOFC-GOLD 2010).

j India's national GHG inventory for 2007, published in May 2010

k Indonesia's Second National Communication

l India's 2009 Forestry Outlook Study for FAO's Asia-Pacific Forestry Sector Outlook Study II, completed by India's Ministry of Environment and Forests.

m Brazil's Second National Communication submitted to the UNFCCC in 2010

n Only for the Amazon forest basin; limited monitoring activities have been completed for other Brazilian forest biomes.

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