

"Reduction of Tropical Deforestation and Climate Change Mitigation"

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MONITORING TROPICAL DEFORESTATION FOR EMERGING CARBON MARKETS

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Abstract

The ability to quantify and verify tropical deforestation is critically important for assessing carbon credits from reduced deforestation. Analysis of satellite data is the most practicable approach for routine and timely monitoring of forest cover at the national scale. To develop baselines of historical deforestation and to detect new deforestation, we address the following issues: 1) *Are data available to monitor and verify tropical deforestation?*: The historical database is adequate to develop baselines of tropical deforestation in the 1990's and current plans call for the launch of a Landsat class sensor after 2010. However a coordinated effort to assemble data from Landsat, ASTER, IRS, and other high resolution sensors is needed to maintain coverage for monitoring deforestation in the current decade and to ensure future observations; 2) *Are there accepted, standard methods for monitoring and verifying tropical deforestation?*: Effective methods for nearly-automated regional monitoring have been demonstrated in

the research arena, but have been implemented for operational monitoring only in a few cases. It is feasible to establish best practices for monitoring and verifying deforestation through agreement among international technical experts. A component of this effort is to define types of forest and forest disturbances to be included in monitoring systems; and

3) *Are the institutional capabilities in place for monitoring tropical deforestation?:* A few tropical rainforest countries have expertise, institutions, and programs in place to monitor deforestation (e.g. Brazil and India) and US and European institutions are technically able to monitor deforestation across the tropics. However, many tropical countries require development of national and regional capabilities. This capability underpins the long-term viability of monitoring tropical deforestation to support compensated reductions. The main obstacles are budgetary, logistical and political rather than technical.

Introduction

A functional system providing carbon credits to tropical countries for reduced deforestation in the international carbon emission trading arena depends on accurate and timely monitoring. The concept of compensated reduction considers the entire forest area within a country to ensure overall net reduction at a national scale (Santilli et al. in press). Monitoring systems must consequently cover large forest areas at repeated intervals, with results available on a time scale that is relevant for decisions about carbon credits. Analysis of satellite data, combined with local expertise and field validation to assure accuracy, is the only practical way to achieve these objectives (Skole et al. 1997).

Currently, established systems are in place to satisfy the monitoring requirements for compensated reductions in only a few tropical countries. The United Nations Food and Agriculture Organization publishes national-level data on forest cover at decadal intervals based on national reporting and limited remote sensing analysis (FAO 2000). A few countries have institutions to monitor forest cover that have been in place for several decades, most notably Brazil (INPE 2000) and India (Forest Survey of India 2001). Most other tropical rainforest countries, however, do not currently have such capabilities.

In addition to the experiences of the few countries that monitor deforestation, several decades of research have generated methods and data sets that lay the groundwork for routine monitoring of tropical deforestation (Mayaux et al. 2005). This research has identified major areas where tropical deforestation has occurred in the last few decades (Lepers et al. 2005) and the multiple factors causing deforestation (Geist and Lambin 2001; 2002). The methods for analyzing satellite data provide spatially-explicit estimates that can be verified by local experts and field observations. As yet, the transition from this research base to an operational monitoring system spanning the entire tropical belt has not occurred.

This paper addresses the technical and institutional issues that need to be addressed in order to achieve a functional system for monitoring tropical deforestation in support of compensated reductions. The paper results from a workshop held in July, 2005 in Washington, DC that brought together remote sensing experts to assess current capabilities and needs to establish baselines and monitor tropical deforestation for compensated reductions (Appendix A). Workshop participants identified the following key questions:

- *Are data available to monitor and verify tropical deforestation?*
- *Are there accepted, standard methods for monitoring and verifying tropical deforestation?*
- *What types of forest and forest disturbances should be included in monitoring systems for carbon credits?*
- *Are the institutional capabilities in place for monitoring tropical deforestation?*

The following sections discuss each of these issues, focusing on current capabilities and the issues that need to be addressed to move towards timely, verifiable, and accurate information as a basis for carbon credits from reduced deforestation.

Are data available to monitor and verify tropical deforestation?

The efficacy of a tropical deforestation monitoring capability rests upon the timely availability of satellite imagery. Historically, this has been difficult to achieve because the satellite sensors with sufficiently high spatial resolution (e.g., Landsat) were not intended as global “wall-to-wall” mapping missions. Computational methods and systems were also not formerly available to ingest large numbers of high-resolution images for regional and pan-tropical mapping. These limitations have largely been lifted in the past 5 to 10 years, by way of advances in both the satellite data acquisition and processing arenas. In particular, the introduction of the Long Term Acquisition Plan (LTAP) for Landsat 7 data collection greatly increased the acquisition of cloud free images in tropical areas (Arvidson et al. 2001).

Despite these limitations, research groups have carried out country-wide analyses of deforestation during the decades of the 1980s and 1990s for several tropical countries from Landsat Multispectral Scanner System (MSS) and Thematic Mapper (TM) data from the 1970s and 1980s (Skole and Tucker 1993; Tucker and Townshend 2000; Steininger et al. 2001). The freely available NASA Geocover Landsat database for the 1990s and 2000 is providing the basis for country-wide analyses during the 1990s (M. Steininger, pers. comm.). However, for the current mid-decade, a similar high resolution data set is needed but will not be available without international coordination and adequate funding.

An increasing number of satellites with higher spatial resolution are providing routine access to limited regional ($< 40,000 \text{ km}^2$) area coverage per image. Satellite sensors such as Landsat TM and ETM+ (USA), Terra ASTER (USA-Japan), CBERS-2 (China-Brazil), SPOT MSS (France), and IRS-2 (India) provide data required for high-resolution mapping of deforestation, logging, and other tropical forest disturbances (Table 1). Limitations in computation for analysis of these imagery, cost, and acquisition strategies that do not cover the entire tropics have necessarily limited their utility to small regions. However, new high-volume, automated processing techniques are now allowing organizations to map forest disturbances at the scale of 2-5 million km^2 per year (INPE 2000; Asner et al. 2005). Yet, current lack of available high resolution, cloud-free data that cover the entire tropics limits possibilities for applying these techniques at repeated time intervals, particularly since the technical problems with the Landsat 7 mission (see below).

National-level monitoring efforts in tropical rainforest countries are hindered by the cost and lack of regular acquisitions with high resolution sensors such as Landsat. Frequent cloud cover makes it necessary to acquire many observations (Asner 2001) as well as radar imagery (Wilkie and Laporte 2001; LaPorte et al. 2004). Current acquisitions strategies do not have this capability, although the LTAP for Landsat 7 has demonstrated the benefits of a comprehensive acquisition strategy. Those tropical countries with deforestation monitoring capabilities in place have overcome these difficulties by acquiring and processing data directly at a receiving station (e.g. Brazil) and by launching national satellites (e.g. CBERS, IRS).

With the launch of the NOAA AVHRR, CNES SPOT, NASA Terra, Aqua, and ESA ENVISAT satellites, and the freely available data from the coarse resolution (250m to 1km) sensors onboard these platforms, it is now possible to monitor large deforestation events on a routine basis. In particular, the Moderate Resolution Imaging Spectrometer (MODIS) onboard the Terra and Aqua satellites allows accurate identification of deforestation events greater than approximately 10 hectares (Anderson et al. 2005; Morton et al. 2005). The Brazilian Institute for Space Research (INPE) has developed an early warning system using Terra MODIS data to map large deforestation events on a near real-time basis (<http://www.obt.inpe.br/deter/>).

The two types of satellite sensing systems – moderate spatial resolution/global versus high spatial resolution/regional – are likely needed for monitoring tropical deforestation (Skole et al. 1997). Global sensors (e.g. MODIS) provide timely detection of large deforestation events and regions of increased forest clearing activities. High resolution sensors (e.g., Landsat) provide regional mapping capabilities that provide

information on the ubiquitous small-scale (< 10 ha) deforestation and forest disturbance events that occur. A multi-sensor approach is needed to map large-scale events, and then to zoom to large regions (< 100,000 km²) for detailed measurements. A stratification of the global survey data would provide a means to automatically zoom into the most important regions in any given year. This general type of approach has already been successfully employed for mapping large deforestation events and for estimating the area of smaller events using the zoom capability along with geo-statistical modeling techniques (Achard et al. 1998; Morton et al. 2005) (Figure 1).

Despite the development of global-coverage satellite sensors (e.g., Terra MODIS, SPOT-VGT) and advances in analytical computation techniques used for forest mapping, a major problem currently exists with Landsat 7, the most widely used and most freely available high spatial resolution imagery worldwide. The primary sensing system aboard Landsat 7 is the Enhanced Thematic Mapper Plus (ETM+). In 2003, ETM+ sensor encountered a major malfunction in one of its components, which severely restricts the ability to detect deforestation to a narrow strip in the center of each image. Given that nearly all of the major deforestation mapping projects around the world rely upon Landsat data, the gravity of this issue cannot be over-emphasized. Replacement of a Landsat-class instrument is not scheduled until at least 2010, when the sensor is currently scheduled to be launched on board the US National Polar-orbiting Operational Environmental Satellite System (NPOESS) system. Other sensors, such as Terra ASTER and SPOT-MSS have very low geographic coverage, precluding their use in large regional mapping projects. Imagery from other sensors such as the Linear Imaging Self Scanning Sensor of the Indian Remote Sensing satellites such as IRS-2 are currently

unaffordable for pan-tropical studies. The Indian AWiFS on IRS-2 may be able to provide useful data if an appropriate acquisition strategy can be developed. Also, Landsat 5 can be acquired but only for locations where direct transmission to a ground receiving station is possible. Still other sensors on board the China-Brazil Earth Resources Satellite (CBERS) are costly and not yet widely used for deforestation monitoring.

In summary, satellite data from a combination of sensors can effectively identify tropical deforestation. Data are available to identify historical deforestation in the 1990s. However, until the current plan to launch a Landsat class sensor after 2010 is realized, current limitations in the availability, cost, and acquisition strategies for high resolution data from Landsat, IRS, ASTER, and other sensors must be resolved to enable routine monitoring of tropical forests in this decade.

Are there accepted, standard methods for monitoring and verifying tropical deforestation?

Previous efforts to identify tropical deforestation

Past efforts to monitor deforestation and report changes in forest cover have used a variety of approaches. The UN Food and Agriculture decadal reports on the state of the world's forests are based on country reporting at the national level and remote sensing at a continental to global level (FAO 2000). The national-level aggregation of these statistics limits possibilities for their use in verifiable and transparent monitoring for

carbon credits. Other efforts at continental and global scales have used a “hotspot” approach whereby expert opinion identifies areas of rapid change for more detailed analyses with high resolution data (Achard et al. 2002) or coarse-resolution data to identify major areas of change (DeFries et al. 2002; Hansen and DeFries 2004). Wall-to-wall analyses with high resolution data have been carried out for some tropical countries for the 1970s and 1980s (Skole and Tucker 1993). Current work is underway for similar analyses for the decade of the 1990s (Steininger, pers. comm.; Plumptre et al. 2003). Brazil’s digital PRODES program, which distributes spatially-explicit estimates of annual deforestation throughout the Brazilian Amazon, and DETER for locations of new deforestation greater than 25 ha in near real-time every two weeks, are based on a combination of medium and high resolution data using a mixture model approach to identify changes in fraction of bare soil and vegetation (Shimabukuro et al. 1998; Anderson et al. 2005; Shimabukuro et al. 2005).

Existing analyses of tropical deforestation cover varying time periods and spatial extents (Table 2). Many of these analyses are not currently available digitally. Using these sources for establishing baselines of forest extent and prior deforestation rates requires harmonizing these multiple sources at different spatial resolutions, area covered, and time periods included. Lepers et al (2005) assembled many of these data sets to identify locations of most rapid deforestation in the last twenty years.

Access to large volumes of high resolution data has improved recently through NASA’s global orthorectified data set initiatives and the associated data distribution capabilities afforded by the Global Land Cover Facility (GLCF) and the Tropical Rain Forest Information Center (TRFIC) (<http://glcf.umiacs.umd.edu/index.shtml>,

http://bsrsi.msu.edu/trfic/data_portal.html). Methods for analyzing large volumes of data have become feasible due to improved computational and data storage capabilities as well as development of automated methods. Early efforts to monitor deforestation with satellite data relied on time-consuming and labor-intensive visual analysis of satellite images. A variety of automated approaches have been developed which greatly reduce the processing time with enhanced accuracy (Asner et al. 2005; Shimabukuro et al. 2005).

Towards Methods for Monitoring Tropical Deforestation

Despite the advances in capabilities for monitoring deforestation, standard protocols, accuracy requirements, and accepted methods have not been defined. No single method is applicable in all situations. Rather, the method depends on the types of forest cover and disturbances of interest. For example, identifying deforestation in seasonal dry forests requires use of data from multiple times per year, whereas deforestation in evergreen forest can be identified with only a single cloud-free observation in a year. Identifying clearings for small fields or selective logging requires higher resolution than large clearings for mechanized agriculture (Souza and Barreto 2000; Souza et al. 2003), so that the appropriate method and data source depend on the type of forest disturbance to be monitored.

Verification and validation is a key component of monitoring systems that has been carried out only to a limited extent in previous efforts. Verification on the ground can only realistically be done for a small subset of locations. Overflights and very high resolution data such as IKONOS and QuickBird provide verification over a larger sample

than ground observations, though expense and data processing precludes coverage of extensive areas.

Establishing guidelines and best practices based on accepted, existing standard methods for monitoring tropical deforestation for carbon credits involves recognition of the following:

- appropriate methods vary with the type of forest, deforestation process, size of clearings, and sensor used for monitoring;
- delineation of the area to be monitored based on a previously-established baseline of forest extent allows consistent results not possible if the target area varies between monitoring periods;
- verification of a representative sample of sites with ground or very high resolution data is critical for applying results for carbon crediting. Protocols are needed for assessing the accuracy of deforestation monitoring systems.
- establishing baselines for forest extent and deforestation area in prior decades requires combining and harmonizing previous results and additional analysis to develop baselines where they currently do not exist;
- a monitoring strategy that combines approaches to identify deforestation “hotspots” and high resolution coverage within the hotspots where computing, data storage, and data availability limit wall-to-wall analysis.

In summary, a variety of methods have been developed to effectively monitor and verify tropical deforestation. The appropriate method varies with the type of forest and disturbance; no single method is most appropriate for all situations. It is feasible for

technical experts to define best practices and acceptable methodologies to monitor tropical deforestation for compensated reductions.

What types of forest and forest disturbances should be included in monitoring systems for carbon credits?

A clear and unambiguous definition of deforestation is central to an effective monitoring program for carbon credits. The Intergovernmental Panel on Climate Change report on Land Use, Land Use Change, and Forestry includes multiple definitions (Watson et al. 2000). The most straightforward definition is the “permanent removal of forest cover,” (Forests are defined as land with more than 10% tree cover. In the framework of the Kyoto Protocol, forest is defined by the respective host country within the ranges of “an area of at least 0.05 to 1 hectares of trees, with a canopy cover of at least 10 to 30%, and with trees capable of reaching 2 to 5 m”). Development of a monitoring system for carbon credits should refine this broad definition of deforestation to clarify:

What types of forest disturbances result in “permanent removal”?

Removal of forest cover results from a variety of processes (Table 3). Some processes, such as hurricanes, floods, and some fires are not human-induced and are outside the realm of the definition of deforestation for the purpose of carbon credits. Human-caused forest disturbances include selective logging, clear-cut logging, clearing for shifting cultivation, human-induced fires, and removal of forest for agricultural expansion, urban growth, or other human uses. Generally, selective logging results in many small forest canopy gaps (each < 30 x 30 m) that can be detected with very high

resolution data or with techniques that identify sub-pixel composition of vegetation components (Stone and Lefebvre 1998; Souza et al. 2003; Asner et al. 2004). Selective logging is not often a “permanent removal” of forest cover, unless the damage is excessive (e.g., via high-grading or multiple-entry harvesting). Clearing for shifting cultivation is part of a dynamic clearing-planting-fallow cycle that can easily be mistaken for new deforestation in a monitoring system if areas currently used for shifting cultivation are not excluded from the analysis. A carbon credit system needs to clearly define the types of forest disturbances included in a monitoring system.

A monitoring system also needs to specify the minimum clearing size to be identified. The smallest unit for assessing land use changes under the Kyoto Protocol is 0.05ha. For compensated reduction, the minimum size would depend on the types of forest disturbances included and the feasibility of accurate detection by available satellite sensors. The Brazilian PRODES monitoring system identifies six hectares as the minimum detectable clearing size using Landsat data at 30m resolution (INPE 2000). Coarser resolution sensors such as MODIS (250-1000 m) can identify larger clearings. Several simple algorithms reliably identify clearings greater than approximately 10 hectares with MODIS 250m data (Morton et al. 2005).

The appropriate minimum size also depends on the relative contributions of different size clearings to overall deforestation area. Where large clearings contribute the majority of deforestation area but a minority of deforestation polygons, a relatively large minimum size is appropriate. Larger minimum size increases the accuracy and eases the logistics of monitoring. Because the smallest detectable change in forest cover is sensor-

dependent, sub-pixel detection thresholds need to be established for each sensor used in the monitoring system.

What forest types are included and what is the spatial extent to be monitored?

A system that repeatedly monitors deforestation needs to be based on an initial delineation of forest to be included in the analysis. Clarification of which forests types to include within the delineated area needs to be explicitly addressed, e.g. whether a monitoring system should extend over only humid tropical forests or should include dry tropical forests. Data sources to determine the initial extent of forest to be analyzed can generally be identified through country-level maps, global remote sensing products, e.g. (Hansen et al. 2003), or prior country-wide analyses to determine deforestation rates in previous decades (Steininger et al. 2001).

In summary, a workable system for monitoring tropical deforestation for compensated reductions depends on development of international standards with clear definitions of initial forest extent, types of forest disturbance, and minimum clearing size to be monitored.

Are the institutional capabilities in place?

A successful global tropical forest monitoring program requires participation by organizations from both the technology and applications sectors. Today, a few agencies and academic institutions dominate access to specific remote sensing expertise and computing capability. Governmental institutions such as the Joint Research Center (JRC)

of the European Commission and Brazil's Institute for Space Research (INPE) maintain high-level expertise in remote sensing as well as the computing assets to accommodate the large data volumes and processing expenses required for regional-to-global satellite monitoring.

A few academic and non-government organizations maintain powerful satellite data storage and analysis systems as well, such as the University of Maryland's Global Land Cover Facility (GLCF) and the Carnegie Institution's Landsat Analysis System (CLAS). However, for several of the following reasons, these groups have a limited scope and effectiveness for carbon monitoring. There are too few groups within tropical forest countries that can provide large-scale, high-resolution, timely mapping of deforestation and other forest disturbances. Brazil's deforestation monitoring program in INPE is a rare exception. In-country capabilities are very limited in the pan-Amazon regions, as well as in Africa and Southeast Asia. Therefore, verification and validation of results produced by the United States or the European Union is difficult without substantive collaboration with host countries. Dissemination of information is also severely limited unless host countries are integrally involved in the production process. Moreover, scientific, political and social acceptance of satellite monitoring results requires participation and investment by organizations within country.

The long-term viability of tropical deforestation monitoring rests with development of capabilities for data acquisition, storage, analysis, and dissemination within tropical rainforest countries. As the investments required for receiving stations and establishing institutions are currently not practical for many tropical countries, regional efforts with multi-country participation might prove a feasible alternative.

Developing institutional capabilities for monitoring tropical deforestation calls for a consortium effort that: (1) brings cutting-edge satellite monitoring technology from the North to tropical countries; (2) provides a conduit for validation studies on a timely basis; (3) develops regional capabilities within tropical rainforest countries for data acquisition and analysis, and (4) allows for dissemination of results by both outside and host country stakeholders.

Conclusions and Recommendations

The workshop to examine the technical needs for monitoring tropical deforestation in support of compensated reductions identified the following priorities:

1) Routine monitoring of tropical forests depends largely on access to data from high resolution sensors such as Landsat TM and ETM+, Terra ASTER, and IRS. The historical database is adequate to develop baselines of tropical deforestation in the 1990s. Plans are currently in place for launch of a Landsat-class sensor in approximately 2010, though this is not assured. Current limitations in availability, cost, and acquisition strategies must be resolved to monitor deforestation in the current decade. Coordinated use of existing observational assets is urgently needed until Landsat ETM-class imagery again becomes routinely available.

2) With current data processing and storage capabilities, effective methods are available to monitor deforestation with largely-automated techniques. No single method is

appropriate in all situations. Technical agreement on best practices and appropriate methods in varying forest types and land use practices can be achieved through a coordinated effort to harmonize approaches. Agreement is also needed on specific definitions of forest disturbances and the extent to be considered for compensated reductions.

3) A critical need is to develop national and regional technical capabilities within tropical rainforest countries for acquiring and analyzing satellite data to monitor deforestation. Currently, capabilities and institutions exist in only a few tropical countries and in research facilities and academic institutions in the US and Europe.

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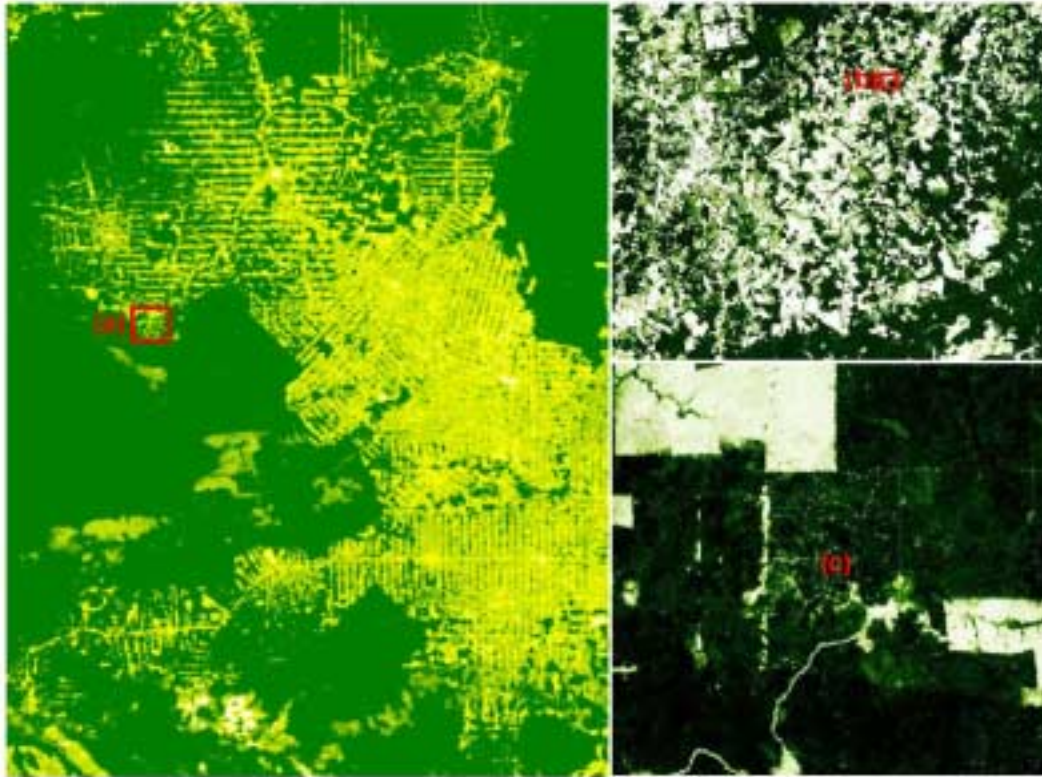
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Figure 1. Example of using multiple sensors to detect tropical deforestation in the State of Rondonia, Brazil. Left image is a Terra MODIS scene of deforestation (yellow areas) in Rondonia, with a small area selected for more detailed analysis using Landsat 7 ETM satellite data (upper right) with further zoom to area in red box showing logging roads and deforestation (lower right).



50 km

Table 1. High and moderate resolution satellite data for pan-tropical deforestation monitoring.

Satellite	Sensor	Spatial Resolution (ground sample distance)	Temporal Resolution (days)	Overall Status
High Resolution (< 50 m)				
Landsat 5	TM	30 m	16	Aging
Landsat 7	ETM+	30 m	16	Crippled by sensor component failure
IRS-2	ResourceSAT	6-56 m	5-24	Unknown availability
CBERS-2				Unknown availability
Terra	ASTER	20 m	26	Acquired on a task by task basis
SPOT	MSS	20 m	26	Acquired on a task by task basis
ERS	Synthetic Aperture Radar	30 m	35	Acquired on a task by task basis
RadarSAT	Synthetic Aperture Radar	8-100 m	24	Acquired on a task by task basis
Moderate Resolution (> 50 m)				
Terra/Aqua	MODIS	250 m 500 m 1000 m	Up to daily	Highly available
TIROS	AVHRR	> 1100 m	Up to daily	Highly available
SPOT	VGT	1000 m	Up to daily	Highly available
IRS	AWiFS	60 m	5	Available
EnviSAT	MERIS	300 m	3	

Table 2. Examples of existing, satellite-derived analyses of tropical deforestation at country-wide, regional, and global scales

Data	Time period	Spatial coverage	Source
Country-wide GEOCover Landsat analyses	1990-2000	10 countries	Conservation International
AVHRR analysis	1982-2000	Global deforestation hotspots	(Hansen and DeFries 2004)
TREES analysis	1990-97	Pan-tropics hotspots	(Achard et al. 2002)
Landsat Pathfinder	1980-90	Pan- Amazon/central Africa	University of Maryland/Michigan State University
Geocover	1980-90	Albertine Rift, Africa	(Plumptre et al. 2003)
Individual country monitoring programs	varies	Country-wide	E.g., (INPE 2000), (Forest_Survey_of_India 2001)

Table 3. Types of clearings for possible inclusion in a global tropical deforestation monitoring system

Type of clearing	Characteristic size	Characteristic temporal cycle
Selective logging	Gaps < 30 x 30 m	30-80 yrs
Clear-cut logging	> several ha	80 yrs
Shifting cultivation	Small fields, < 6 ha	5-10 yrs
Small-holder agriculture	Small fields, < 6 ha	Permanent until abandoned
Intensive mechanized agriculture	> 100 ha	Permanent until abandoned
Urban growth, or other uses	Ranging from small settlements to urban expansion	Permanent until abandoned

APPENDIX A: Participants in Workshop on “Remote Sensing Analysis of Tropical Deforestation and Baselines for Carbon Crediting and Biodiversity”, July 6-7, 2005, Washington, DC

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APPENDIX B. List of acronyms

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AWiFS	Advanced Wide Field Sensor (on IRS)
CBERS	China-Brazil Earth Resources Satellite
CLAS	Carnegie Institution's Landsat Analysis System
CNES	Centre National d'Etudes Spatiales (French space agency)
DETER	Detecção de Desmatamento em Tempo Real (INPE program for Deforestation Detection in Real Time)
ERS	European Remote Sensing
ESA	European Space Agency
ETM	Enhanced Thematic Mapper
FAO	United Nations Food and Agriculture Organization
GLCF	Global Land Cover Facility
IKONOS	High resolution satellite imagery
INPE	Instituto Nacional de Pesquisas Espaciais (Brazilian Institute for Space Research)
IRS	Indian Remote Sensing Satellite
JRC	Joint Research Center (of the European Commission)
LTAP	Long Term Acquisition Plan (for Landsat 7)
MERIS	Medium Resolution Imaging Spectrometer
MODIS	Moderate Resolution Imaging Spectrometer
MSS	Multispectral Scanner System
NASA	National Aeronautics and Space Administration (US space agency)
NOAA	National Oceanographic and Atmospheric Administration
PRODES	Programa de Cálculo do Desflorestamento da Amazônia
SPOT	Satellite Probatoire d'Observation de la Terre
SPOT-VGT	SPOT vegetation sensor
TIROS	Television Infrared Observations Satellite Program
TM	Thematic Mapper
TREES	Tropical Ecosystem Environment Observations by Satellite
TRFIC	Tropical Rain Forest Information Center