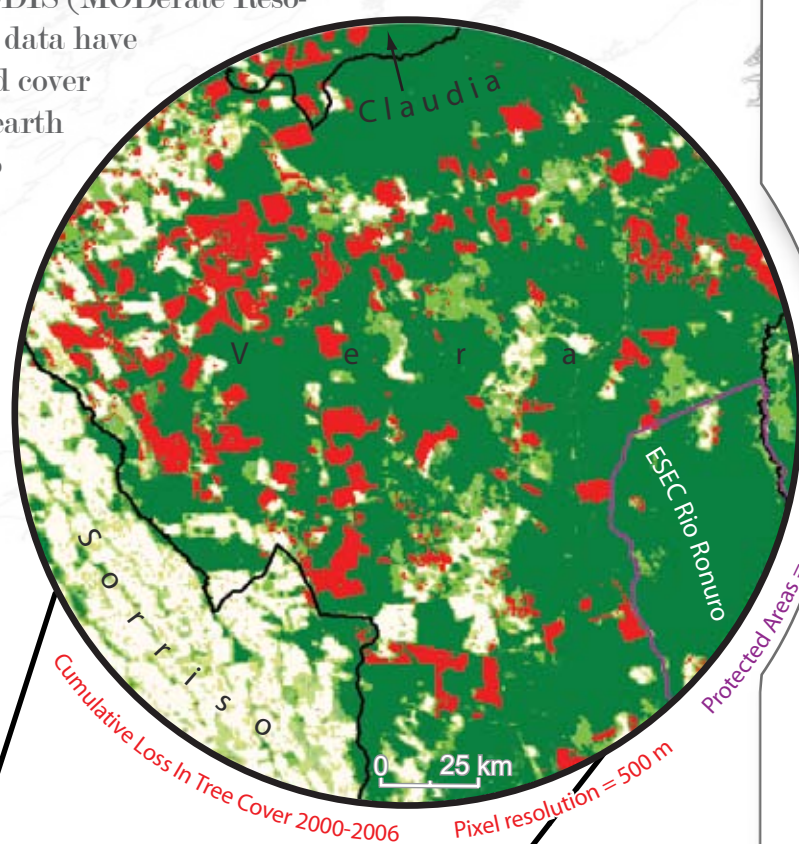


## Tree Cover Loss in the Humid Tropics

Despite the need for accurate, consistent and timely information on change within terrestrial forested ecosystems, no such data exist. Global assessments typically rely on disparate data sets of uncertain quality and accuracy to provide estimates of forest change. This limits the ability of governments and civil society to monitor changes within this important component of the earth system. However, improved mapping techniques and data sources from satellite observations are enabling, for the first time, to cost effectively measure change over time. This new capability to provide timely and reliable information on forest change represents a turning point in environmental monitoring and the use of satellite information to improve the management of the world's forests.

Since 2000, remotely sensed data have been available free of cost from the MODIS (MODerate Resolution Imaging Spectro-radiometer) sensor, operated by NASA. MODIS land data have spatial resolutions of 250 and 500 meters, detailed enough to detect major land cover conversion events. MODIS data are also acquired nearly daily for the entire earth surface, allowing for timely documentation of change dynamics. The MODIS sensor was also engineered with spectral bands specifically designed for land surface monitoring. These combined features provide a unique capability for targeting change at the global scale. When used with finer spatial resolution data (data less frequently acquired) in a sampling framework, an improved monitoring capability is achieved. Currently, there is no systematic global acquisition of the earth surface using high spatial resolution data, except for the now malfunctioning Landsat 7 instrument, the Enhanced Thematic Mapper Plus (ETM+). The current malfunction of the scan-line corrector results in data gaps at the edges of acquired imagery, as can be seen in the included examples.

The main map on this poster highlights a pan-tropical assessment of tree cover change using MODIS data from 2000 to 2006. Change hotspots are highlighted in red and examples of Landsat subsets are included to illustrate the power of MODIS in identifying change and the utility of tree cover change analysis as a tool to better monitor and manage forests.



## Brazil Using Satellites to Monitor Deforestation

**MATO GROSSO STATE, BRAZIL** Tree cover change analysis reveals that the hotspot for deforestation in South America is the Brazilian State of Mato Grosso. Large scale deforestation began in the 1970s and accelerated in the 1990s, with the growth of the soybean industry, fueled by international investment (New York Times). In 2002, the agricultural lands of Mato Grosso and neighboring Maranhão comprised the vast majority of soy production in the Legal Amazon. The Landsat images below show the systematic conversion of forests to agriculture between 1988 and 2005.



Forest converted to soy plantation in Pará, Brazil.

Another significant driver of deforestation is the enormous recent growth of Brazil's cattle industry. From 1990-2002, the number of cattle in the Amazon more than doubled, with most concentrated in the states of Mato Grosso, Pará, and Rondônia (Arima et al., Instituto Brasileiro de Geografia e Estatística).

Whereas many tropical countries lack the capacity to monitor their forests, Brazil has one of the most technologically advanced forest monitoring programs in the world and is taking steps to address deforestation. Since the 1980s, the Brazilian Space Agency (INPE) has been monitoring the extent of deforestation in the Brazilian Amazon based on interpretation of high-resolution satellite imagery, such as Landsat. Building on INPE's deforestation data, the government of the State of Mato Grosso took action to mitigate deforestation by implementing the Sistema de Licenciamento Ambiental em Propriedades Rurais do Estado de Mato Grosso (Environmental Licensing System for Rural Properties in the State of Mato Grosso) in 1999.

During the first two years of the monitoring program, deforestation within Mato Grosso was reportedly cut in half. Despite Mato Grosso's efforts, however, deforestation remains high compared with other Brazilian states (National Public Radio). The system is still being refined to deliver the right information to the right people at the right time. Despite the challenges, this remains an extraordinary and relevant model, particularly at a time when Brazil is transferring forest law enforcement responsibility from the federal level to the state governments.



The satellite images to the left show the systematic expansion of soy plantations in Mato Grosso. Mato Grosso's drier climate makes it an ideal environment for growing soybeans and constructing the roads needed to transport crops to market.

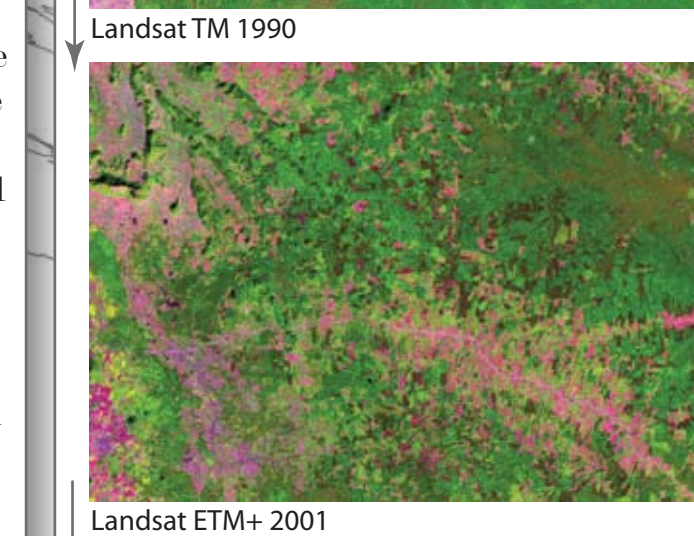
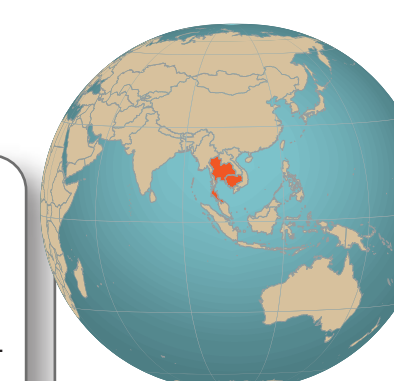
## Rapid Forest Loss Across the Thailand-Cambodia Border

**THAILAND-CAMBODIA BORDER** In 1990, the border region between Thailand and Cambodia was densely forested, but between 2001 and 2005, tree cover change analysis reveals extensive deforestation on the Cambodian side.

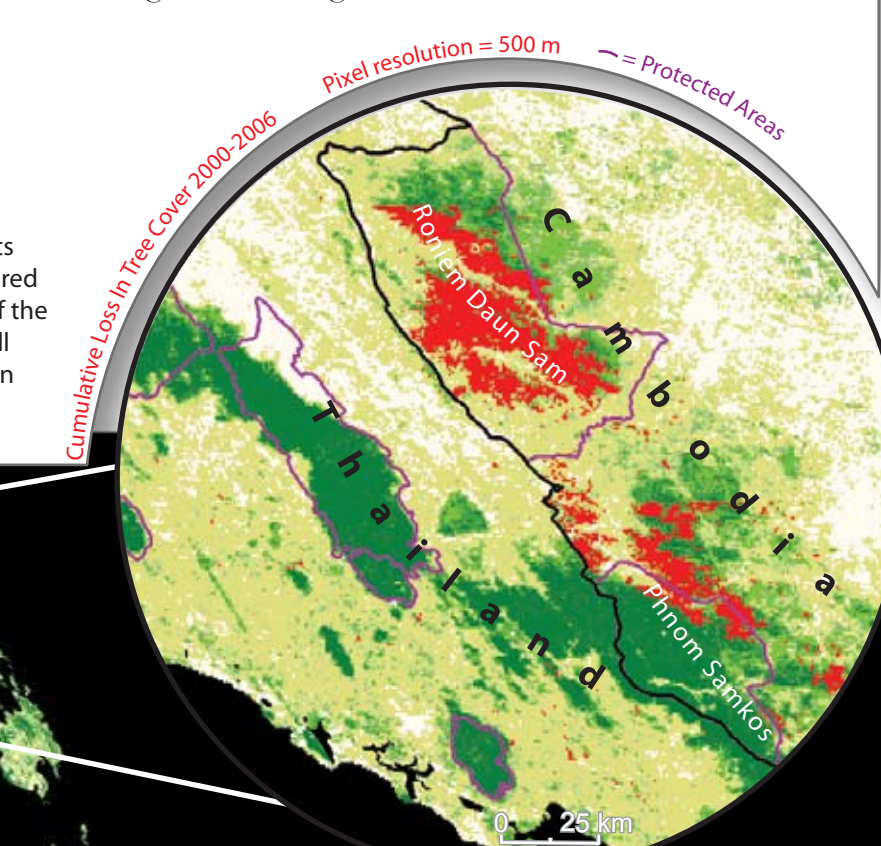
The problem of deforestation along the border between these two countries dates back to at least the early 1990s. After severe flooding linked to deforestation in Thailand, the Thai government banned all timber harvesting in 1989. As a result, timber imports from neighboring countries like Cambodia increased, along with allegations of illegal logging inside Cambodia (American University Trade and Environment Database). Despite attempts to halt the logging in the 1990s, and a 2002 moratorium issued by Cambodia, deforestation has continued (Global Witness).

The Cambodian government is working with a number of independent organizations to address problems of illegal logging.

The inset maps left illustrate the change in tree cover along the Thai-Cambodian border during 2001 to 2005, in comparison with the intact forest that was present in 1990. Large-scale deforestation continues to encroach into national parks, wildlife sanctuaries, and protected areas (e.g. Roniem Daun Sam, Samlaut, Phnom Samkos). Continuing loss of forests stresses the need for improved monitoring and forest governance.



Landsat images show forests being logged and then cleared for agriculture. The effect of the sheer number of these small scale conversions is visible in 2005.



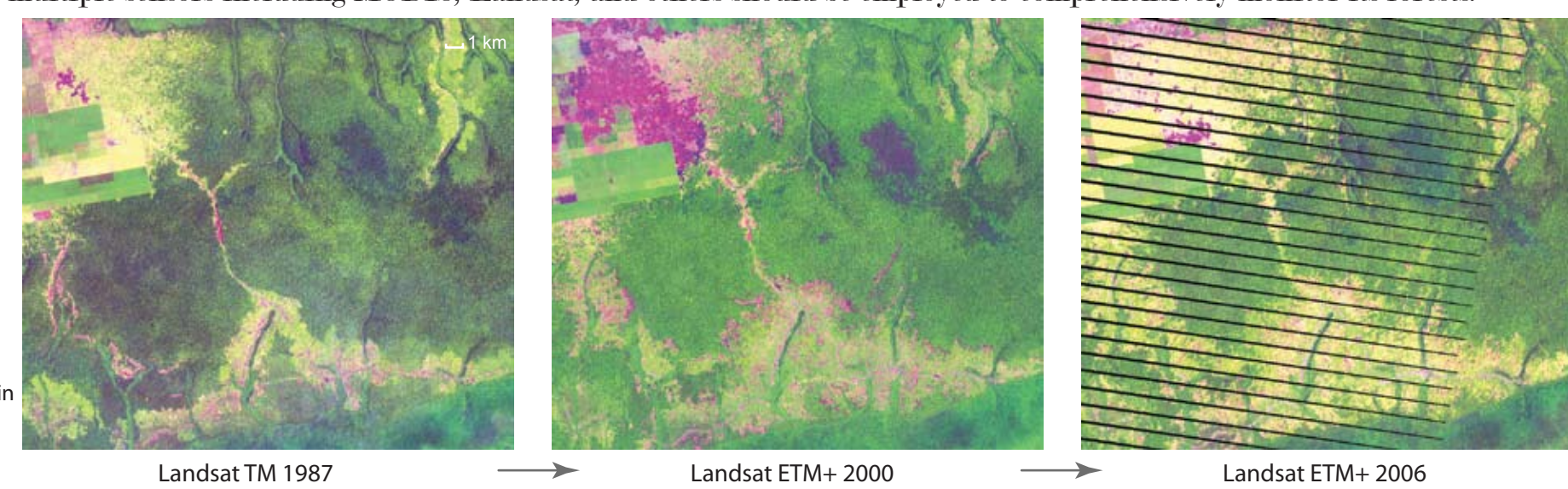
## Agriculture and Selective Logging Impacting Central Africa's Intact Forests

**EQUATEUR PROVINCE, DRC** The resource-rich Democratic Republic of Congo (DRC) contains one of the largest areas of closed-canopy rainforest in the world, covering over 100 million hectares and comprising over half of the forests in the Congo Basin.

DRC has a low rate of deforestation, primarily from clearings for smallholder agriculture expanding along roads. Plantations have been established in some areas, but do not yet cover significant areas. Extensive deforestation occurred near refugee camps in eastern DRC during the 1990s. However, land conversion of the scale that is happening in Brazil (conversion to soybean cultivation) and in Indonesia (rapid expansion of oil palm plantations), is not yet occurring in central Africa.

Logging has a significant impact on forests in central Africa, such as opening remote areas to activities like hunting and settlement, but generally has not led to widespread deforestation. Instead, selective logging predominates because only a few tree species, such as sapelli (*Entandrophragma cylindricum*), are commercially valuable. On average, only one to four trees per hectare are removed, making selective logging difficult to detect with medium to coarse resolution imagery such as MODIS (250m resolution).

In DRC, a decade of civil war led to decline in the forestry sector, with much lower rates of production than other countries in the region, as well as poor forest governance. Currently a reorganization of the forest sector is underway. A component of this reorganization is the establishment of forest monitoring with remote sensing. The pattern of forest development in DRC, however, means that more detailed satellite imagery (such as Landsat) is necessary to track selective logging and the construction of logging roads. Given the challenges posed by Central Africa's dense cloud cover and the small scale of forest change, multiple sensors including MODIS, Landsat, and others should be employed to comprehensively monitor its forests.



Smallholder agriculture expanding into the forest along road networks is visible in this series of Landsat images, with newly cleared or burned areas shown in purple, agriculture in yellow, and degraded forest in light green. Small rectangular plantation areas are visible in the upper left of each image.



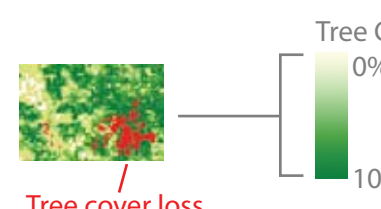
Small-scale clearings west of Beni, in eastern DRC

## TECHNICAL NOTES

Main Map and Circular Insets:  
Tree Cover & Tree Cover Change

The pan-tropical main map and circular insets show tree cover change information over a map of forest cover. The tree cover change map was produced by analyzing 6 years of MODIS data (2000 - 2006). The tree cover change data has a resolution of 500 m. The circular insets show an area that is 150 km across (see Figure 1).

Cumulative tree cover loss was measured by compiling annual change data from 2000-2006. The dataset was then overlaid on tree cover data from 2000. The resulting map depicts tree cover in a continuous gradient from 0 percent to 100 percent (shades of green), and tree cover loss shown in red (see below).



Regional Case Studies:  
Landsat Satellite Imagery

Time series of Landsat images are shown in the regional case studies. Because of Landsat's finer resolution, these images were used to validate the MODIS tree cover change data. The spatial extent of the images is 29 km wide by 25 km high, with a spatial resolution of 30 m (see Figure 2). Images are displayed using a 5-4-3 false color composite band combination.



Pink and purple hues represent cleared areas, with darker shades being bare ground or fire scars (image 1). Yellow hues show agriculture, and greens are forest (image 2). The black stripes seen on more recent Landsat products are data gaps due to a malfunction of the sensor's scan-line corrector (image 3). In some images, white clouds and their shadows are present (image 4).

Percent tree cover data and tree cover change analysis provided by South Dakota State University (SDSU) as part of the NASA Land Cover and Land Use Change Program.

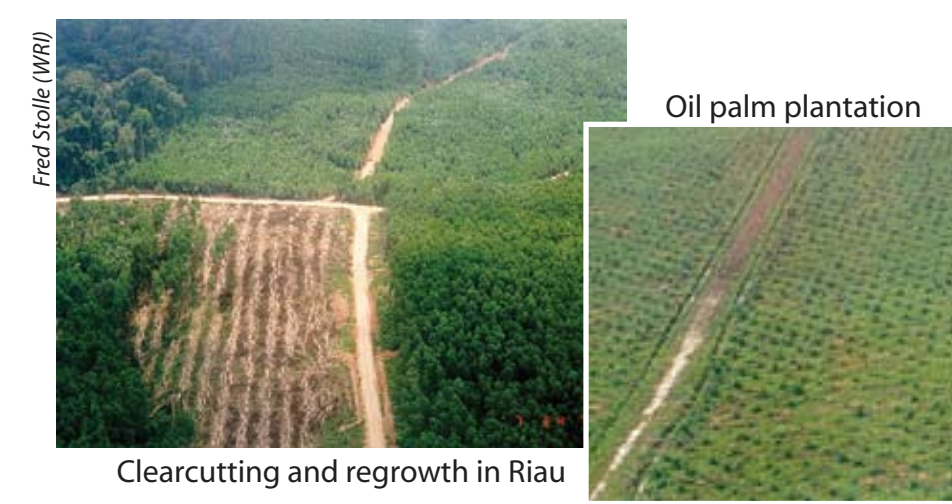
Protected areas data acquired from UNEP-WCMC's World Database of Protected Areas.

## Rush to Biofuels Endangering Indonesian Forests

**RIAU PROVINCE, INDONESIA** Indonesia's deforestation rate is among the highest in the world, with adverse impacts on biodiversity, the provision of ecosystem services, and climate change. Fires associated with forest loss hinder economic activities, transportation, and present serious health risks.

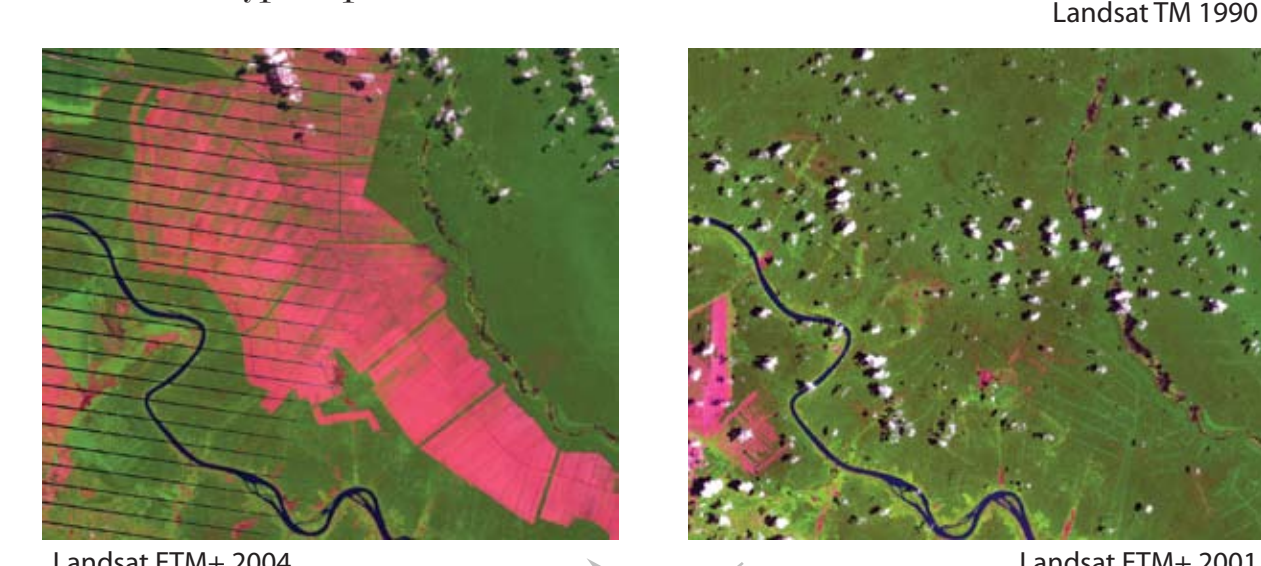
Due in large part to forest loss, Indonesia is the world's fourth largest greenhouse gas polluter, after the U.S., the European Union, and China. Of Indonesia's greenhouse gas emissions, over 80% come from land use change, especially the clearing and burning of peat swamp forests (WRI). Much forest loss is attributed to the conversion of natural forests for plantations and high rates of illegal logging. Despite the substantial availability of non-forested areas, large areas of forest are being cleared and converted to plantations. In early 2007, the Indonesian government announced the intention to establish an additional 5 million hectares of new biofuel plantations, primarily oil palm (Jakarta Post). These new plantations would have a very detrimental effect on Indonesia's carbon emissions if they replace natural forests. If established on already degraded lands, a modest positive impact on emissions is possible.

Monitoring of tree cover is crucial for Indonesia to effectively manage forests and address rapid forest loss. MODIS tree cover analysis reveals the wide scale forest conversion occurring in Indonesia. The typical pattern of forest conversion to plantations is shown in the series of Landsat images to the right. Forests are first logged of valuable species and later completely cleared for conversion to plantations.



Clearcutting and regrowth in Riau

Fred Stolle (WRI)



Multiplying road networks are visible on the 1990 and 2001 images showing the logging that precedes forest clearing. The 2004 image reveals large areas newly cleared for plantations.

Tree cover change analysis: Matthew Hansen (SDSU), Peter Potapov (SDSU), Kyle Pittman (SDSU)

Poster design: Stephen Adam (WRI), Susan Minnemeyer (WRI)

Research partners, support, and data providers

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