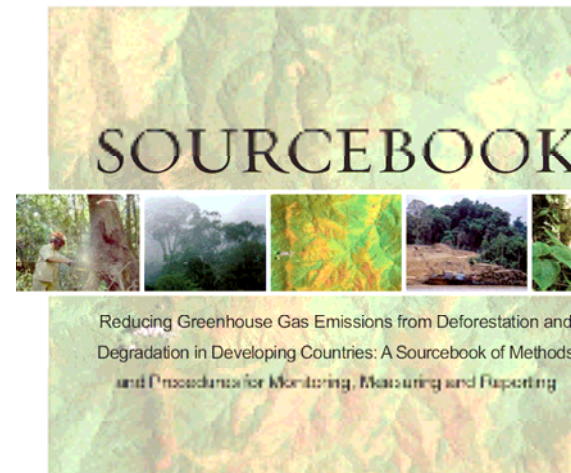


# ***DEFORESTATION IN TROPICAL COUNTRIES: USE OF SATELLITE REMOTE SENSING IN DETECTING AND MONITORING FOREST AREA CHANGES***

***Presented by Frédéric Achard***

***Joint Research Centre of the European Commission***

***Workshop on Methodological Issues relating to  
Reducing Emissions from Deforestation and Forest Degradation in Developing Countries  
25 – 27 June 2008 - Tokyo, Japan***



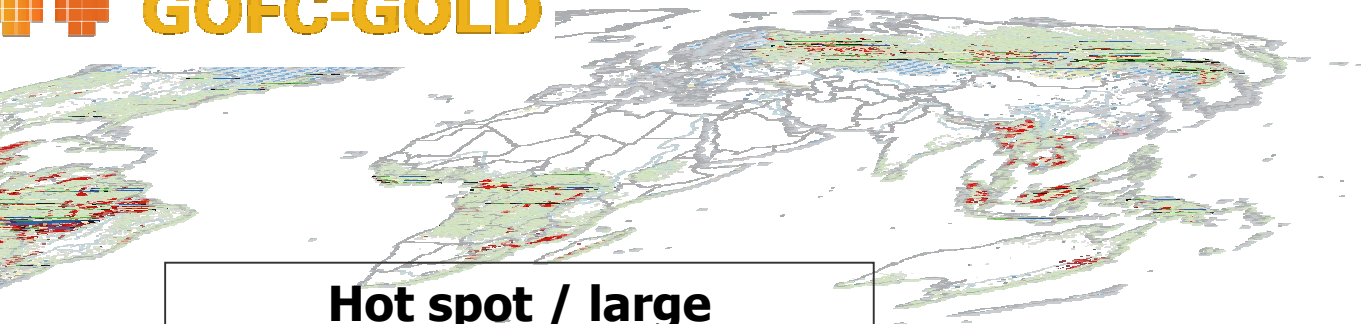
is presentation is based on following sources:

Achard, R. De Fries, M. Herold, D. Mollicone, D. Pandey, C. Souza Jr.  
Guidance on Monitoring of Gross Changes in Forest Area”  
**Chapter 3 of GOFC-GOLD Sourcebook, GOFC-GOLD Report version COP13-2**

Achard, G. Grassi, M. Herold, D. Mollicone, M. Teobaldelli  
Use of Satellite Remote Sensing in LULUCF Sector”  
**Presentation at IPCC Workshop on guidance on estimating emissions and  
removals of GHG from land uses, Helsinki, 12-15 May 2008**

## Content of the Presentation

1. Utility of satellite imagery for forest cover monitoring
2. Availability of current medium resolution satellite imagery
3. Examples of national forest cover monitoring systems
4. Key features for forest cover monitoring from satellites

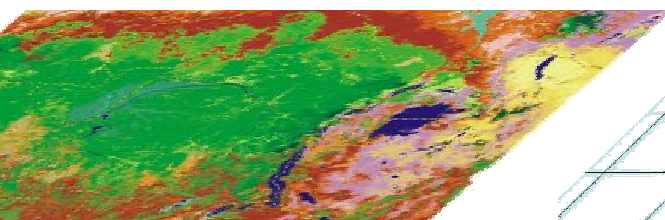


250m – 1km resolution  
Hot spots of forest change  
(deforestation ~10-20 %)

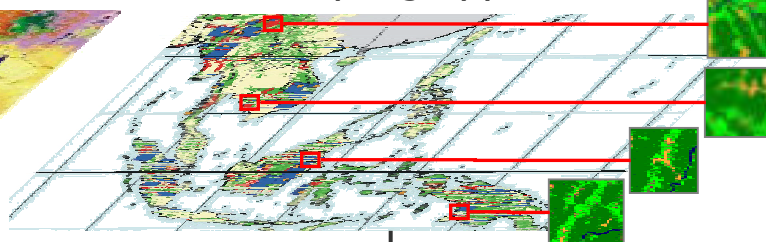
**Hot spot / large  
deforestation detection**

Regional / **National observations**

Wall-to-wall mapping



Sampling approach



10 – 30 m resolution  
(deforestation ~ 0.5-2 %)

**Change in forest  
area**

Fine-scale/ **in-situ observations**

**Estimation of carbon  
emissions**

Forest inventories  
Targeted remote surveys  
FAO statistics  
IPCC-LULUCF / AFOLU

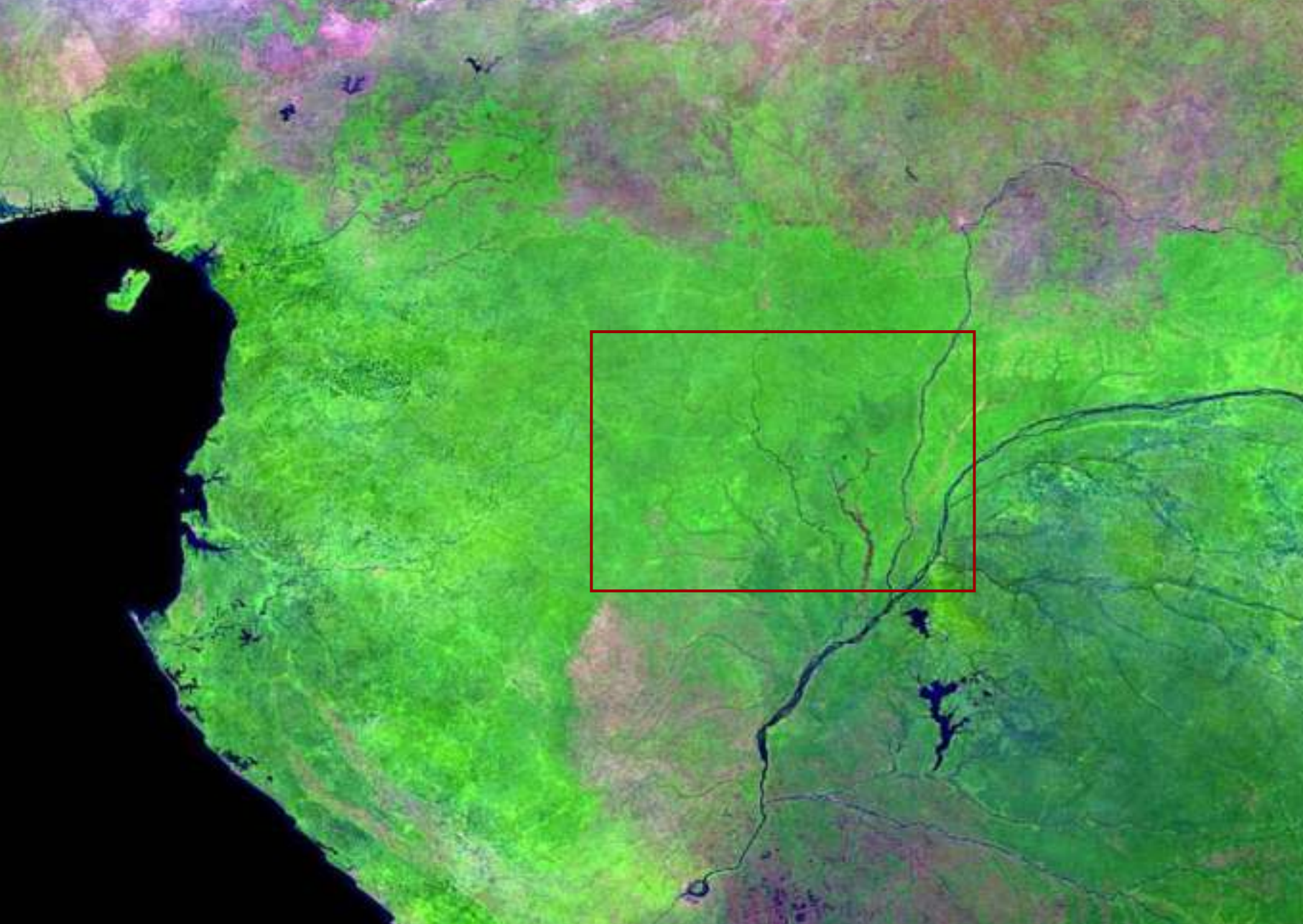




## Utility of optical sensors for monitoring forest cover

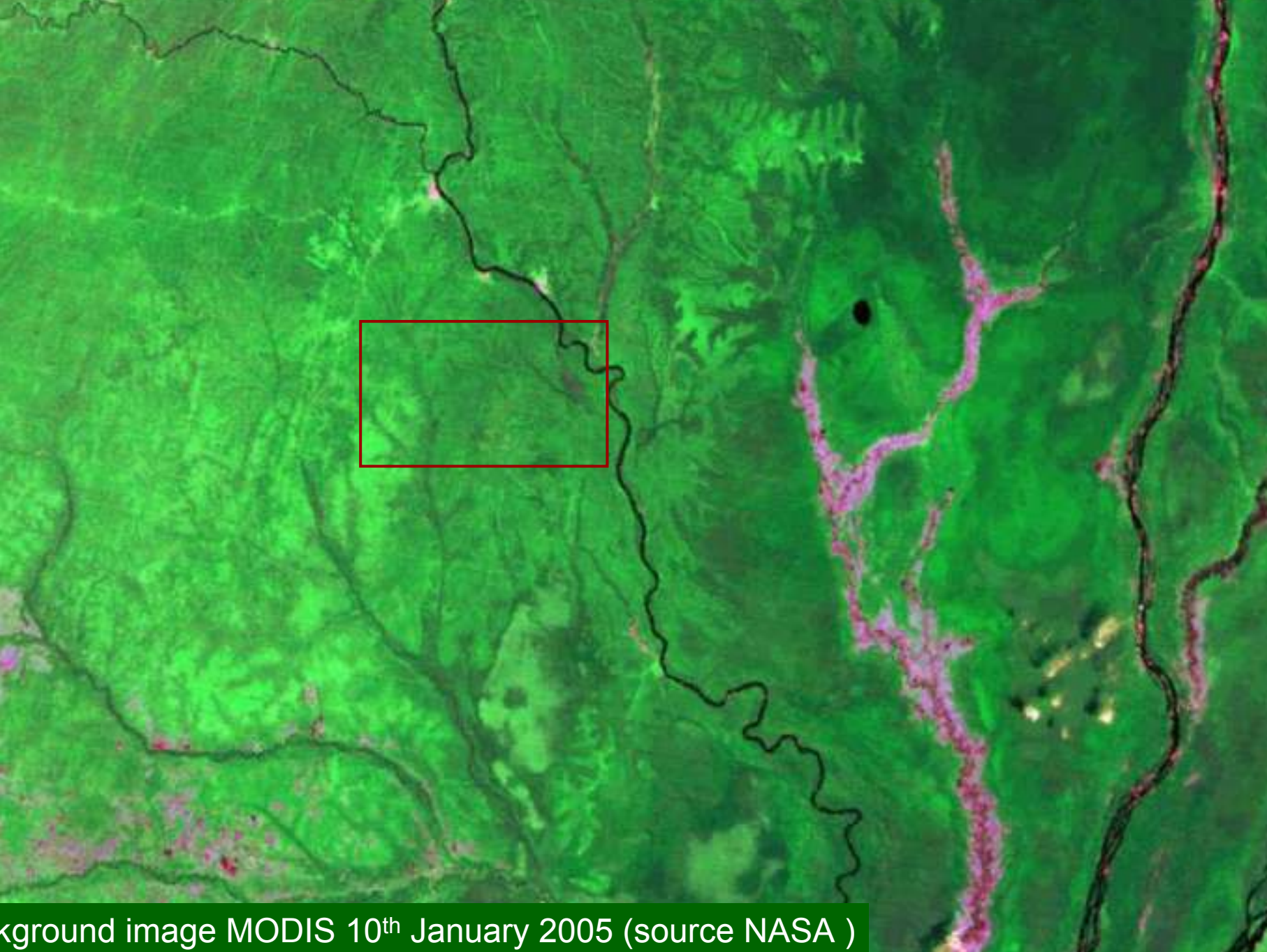
Sensor & resolution	Examples of current sensors	Minimum mapping unit (change)	Cost for data acquisition	Utility for forest cover monitoring
<b>Coarse</b> (250m-1km)	SPOT-VGT: 1998- MODIS: 2000- MERIS: 2004-	> 10-20 ha	Low or free	<b>Consistent pan-tropical annual monitoring</b> to locate “hotspots” for further analysis with mid resolution
<b>Medium</b> (10-60 m)	<b>Landsat</b> TM/ETM <b>SPOT</b> HRV <b>IRS</b> LISS CBERS HRCCD	0.5 - 5 ha	<\$0.001/km <sup>2</sup> for historical data \$0.02/km <sup>2</sup> to \$0.5/km <sup>2</sup> for recent data	<b>Primary tool to map deforestation and estimate area change</b>
<b>Fine</b> (<5 m)	IKONOS QuickBird Aerial photos	< 0.1 ha	High \$2 -30 /km <sup>2</sup>	<b>Validation of results</b> from coarser resolution analysis, and training of algorithms





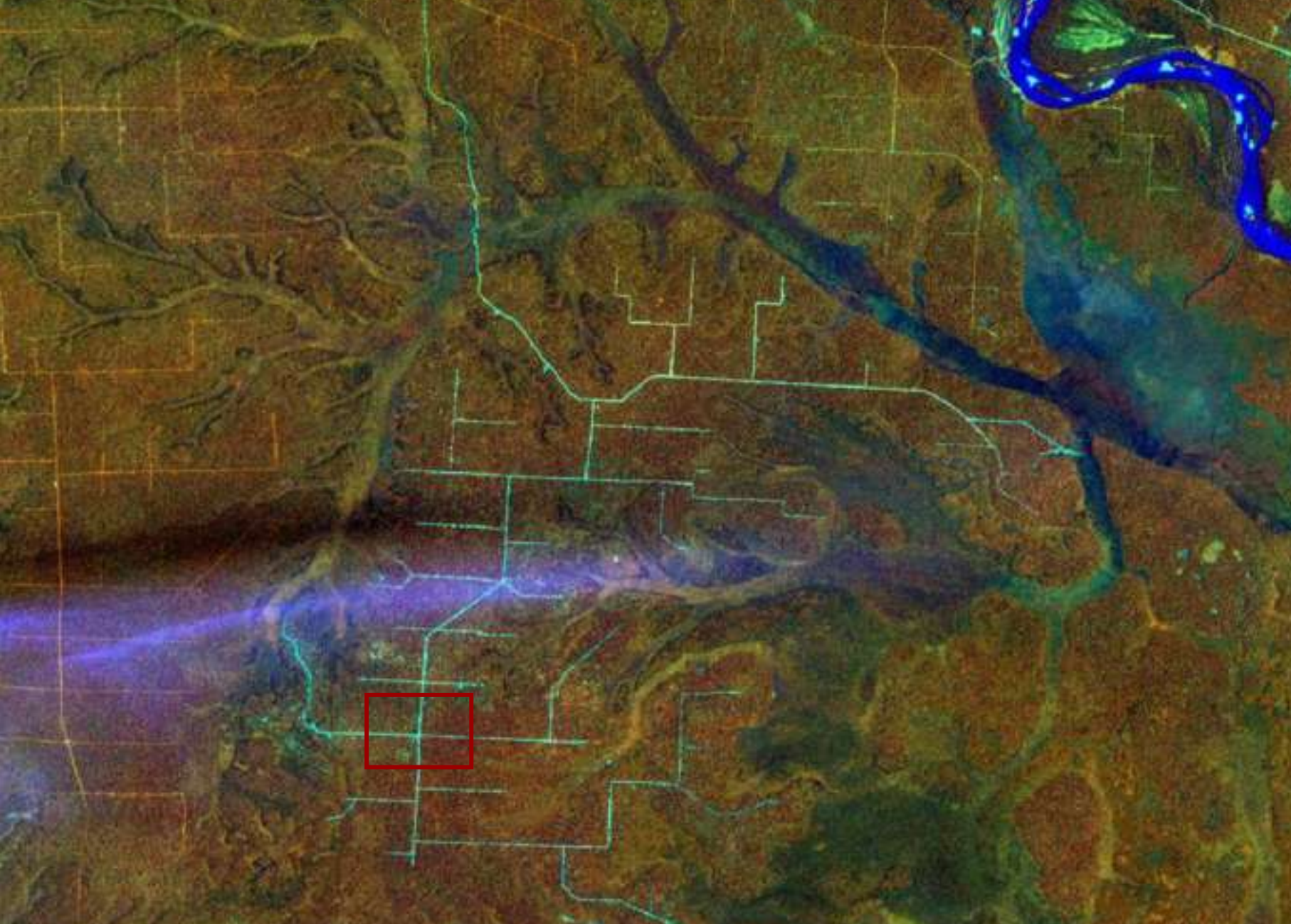
ground image VGT 2000 Mosaic (image source JRC, data source CNES )



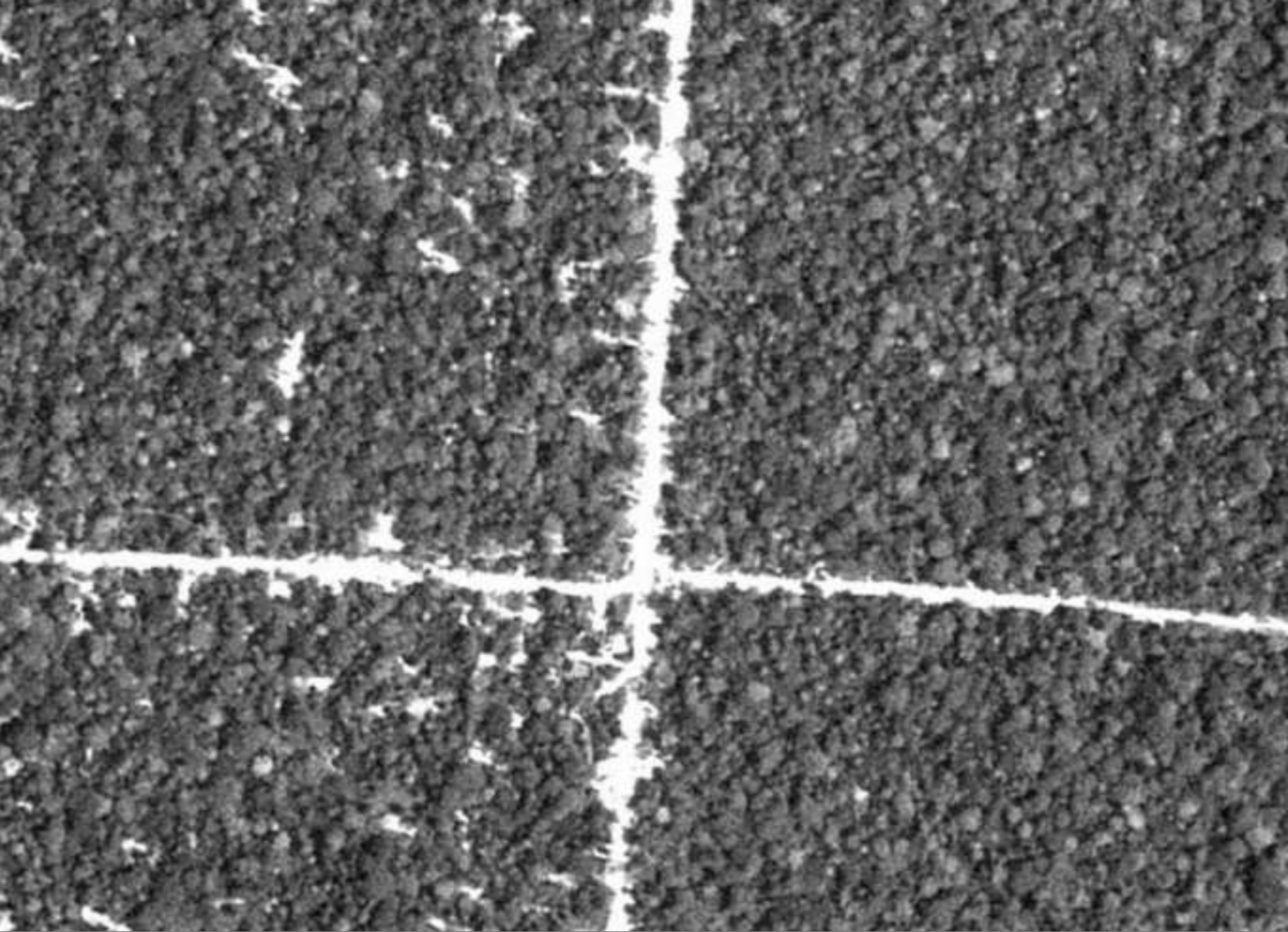


Background image MODIS 10<sup>th</sup> January 2005 (source NASA )





Background image SPOT HRV 10 m March 2005 (image source JRC, data source CNES)



Background image SPOT HRV 2.5 m March 2005 (image source JRC, data source CNES)

## Land cover mapping & monitoring from coarse resolution satellite imagery

### Advantages:

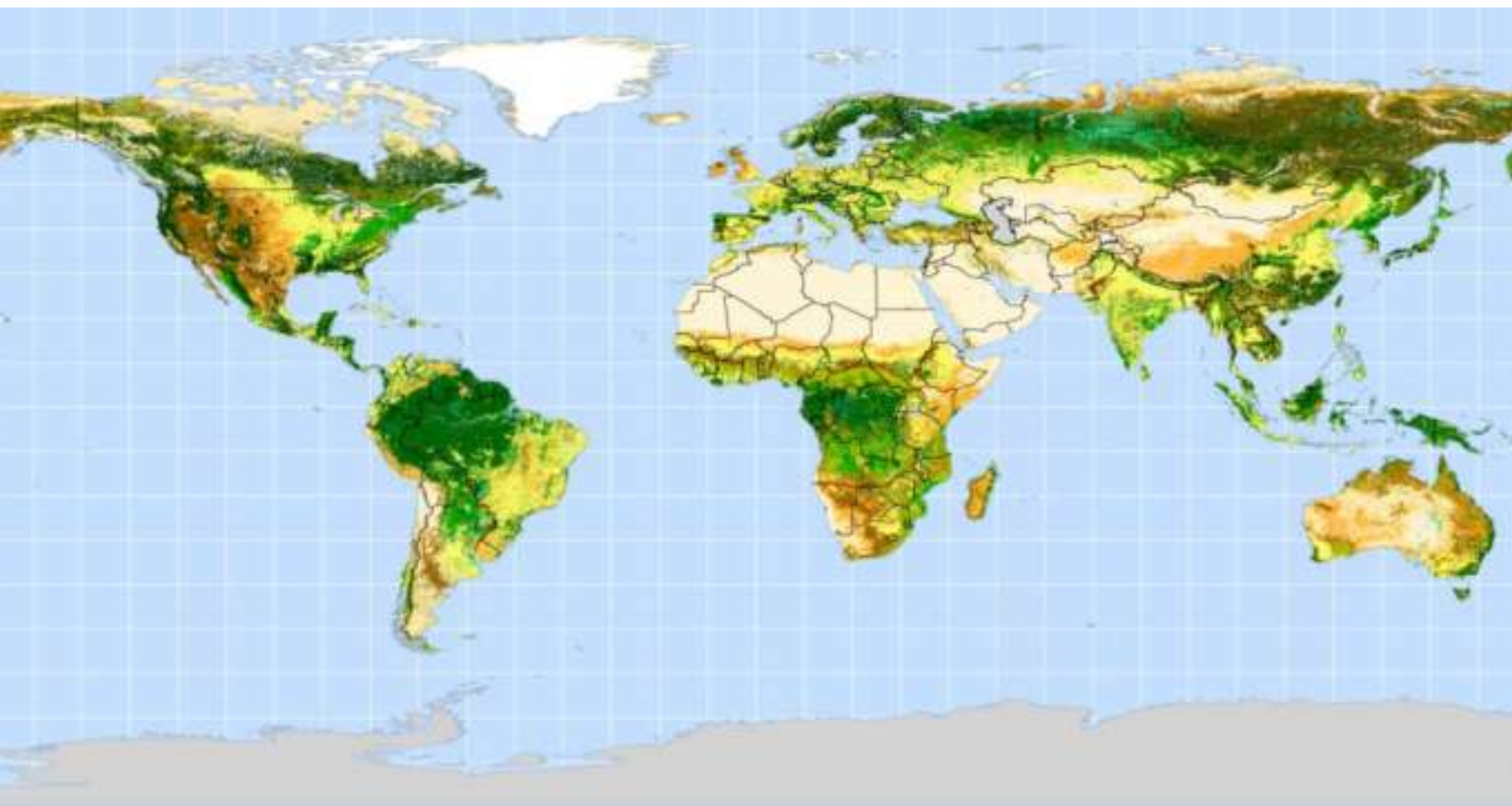
- Free data, less data-intensive analysis
- Daily coverage helps with cloud problems

### Can be used for:

- **Global land cover mapping**
- Global forest monitoring & detection of hot spots
  1. Rapidly identifying major areas of change
  2. **Real-time deforestation monitoring for large clearing**
  3. Determining fate of land use following deforestation



## Example of global land cover dataset: GLC-2000 map



## **Corine Land Cover (CLC-1990 & CLC-2000)**

- Photo-interpretation of Landsat images by 27 National teams
- MMU: 5 ha for change database (1990 -> 2000)
- 44 land cover and use classes
- Thematic accuracy 'Target' is to be 85% correct

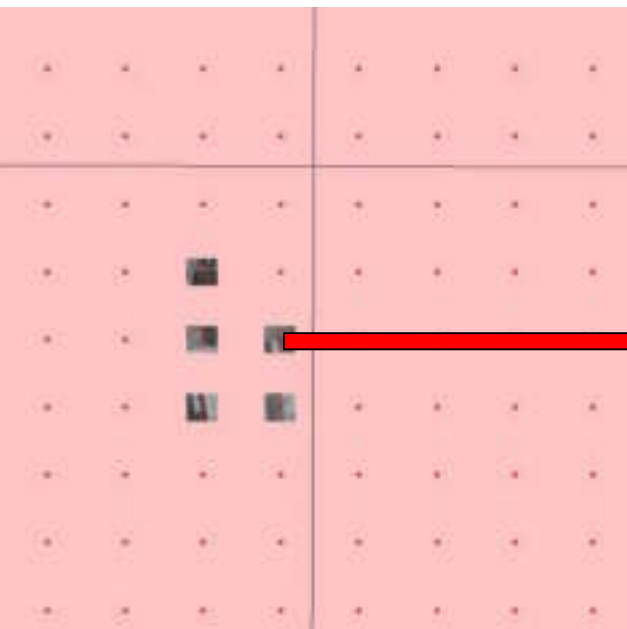
## **Eurostat LUCAS (Land Use Cover Areas Frame Sample Survey)**

- Statistical exercise based on field survey
- Sampling unit = 1,5 m radius point of Land
- Two phase sampling : 1. Regular 2 km grid (stratification) 2. Field survey
- Interpretation of orthophotos (or best available satellite image) of each sam



## First phase: Spatial systematic sample

2 km-square regular GRID



orthophotos interpretation

Stratification in 7 land cover classes



### **LAND COVER**

- 1 ARABLE LAND
- 2 PERMANENT CROPS
- 3 GRASSLAND
- 4 WOODED AREAS AND SHRUBLAND
- 5 BARE LAND, RARE VEGET.
- 6 ARTIFICIAL LAND
- 7 WATER

## Accuracy of stratification

To evaluate accuracy of stratification a comparison has been conducted between classification of the points according to photointerpretation and ground observation (nomenclature of 7 classes)

Unweighted proportion of agreement: 70.8%

**Weighted proportion of agreement: 74.8%**

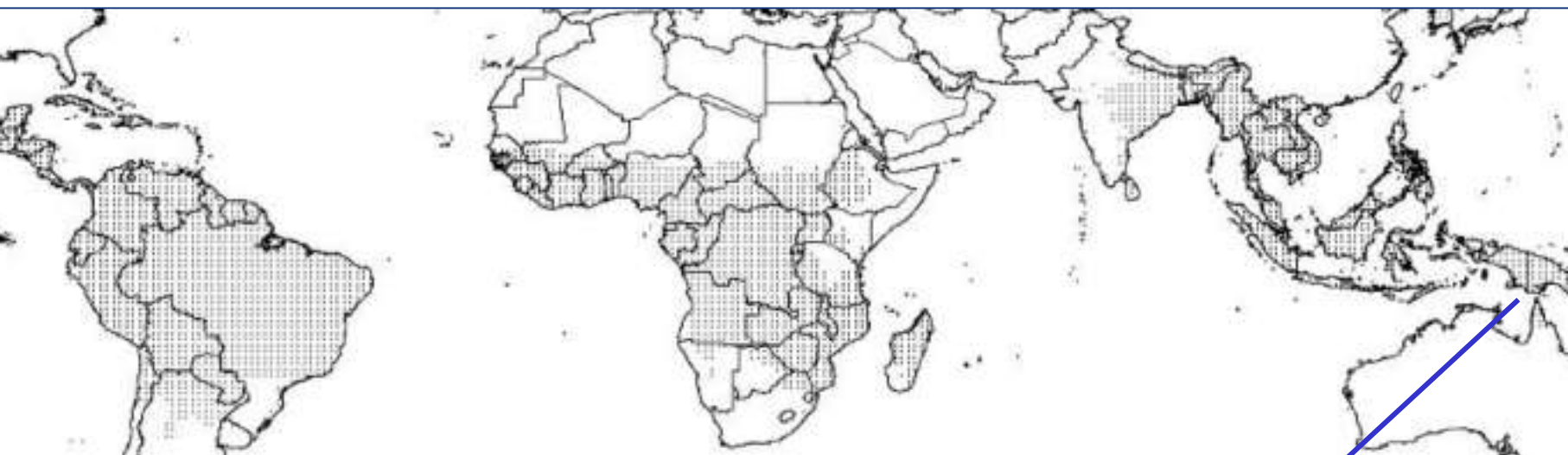
Orthophoto classification is quite accurate but it has to be used only for stratification purposes otherwise estimates are biased)



Ground survey is still necessary any time good quality data are required



Systematic sample grid to estimate forest cover changes between 1990, 2000 & 2005



1990



2000



2005



Samples are 10km x 10km size

## indicative costs of operational monitoring systems using satellite data

- Vanuatu Remote sensing survey  
~ 300.000 US\$ for 1.2 million ha of Land (80 Islands)  
i.e. ~ 25 US\$ / km<sup>2</sup> (includes development of system)
- Indian bi-annual surveys  
~ 1 + 1 M US\$ / survey for 330 million ha of Land  
i.e. ~ 0.60 US\$ / km<sup>2</sup> (routine including field check)
- Brazilian annual satellite surveys (PRODES) :  
~ 1 M US\$ / year for 400 million ha Forest  
i.e. ~ 0.25 US\$ / km<sup>2</sup> (routine)
- FAO FRA 2010 Remote Sensing Survey  
~ 5 M US\$ for 30 million ha of Land (1% Tropics)  
i.e. ~ 15 US\$ / km<sup>2</sup> (includes development of the system)

## Key methodological features for forest cover monitoring from satellite remote sensing

Monitoring deforested area can be done with confidence with a variety of methods

Monitoring degraded forest area is more challenging

Local expert information is needed to support interpretation of R data

Landsat-TM type satellite data around years 1990, 2000 and 2005 will be most suitable to assess historical rates of forest cover changes with MMU of less than 1 ha

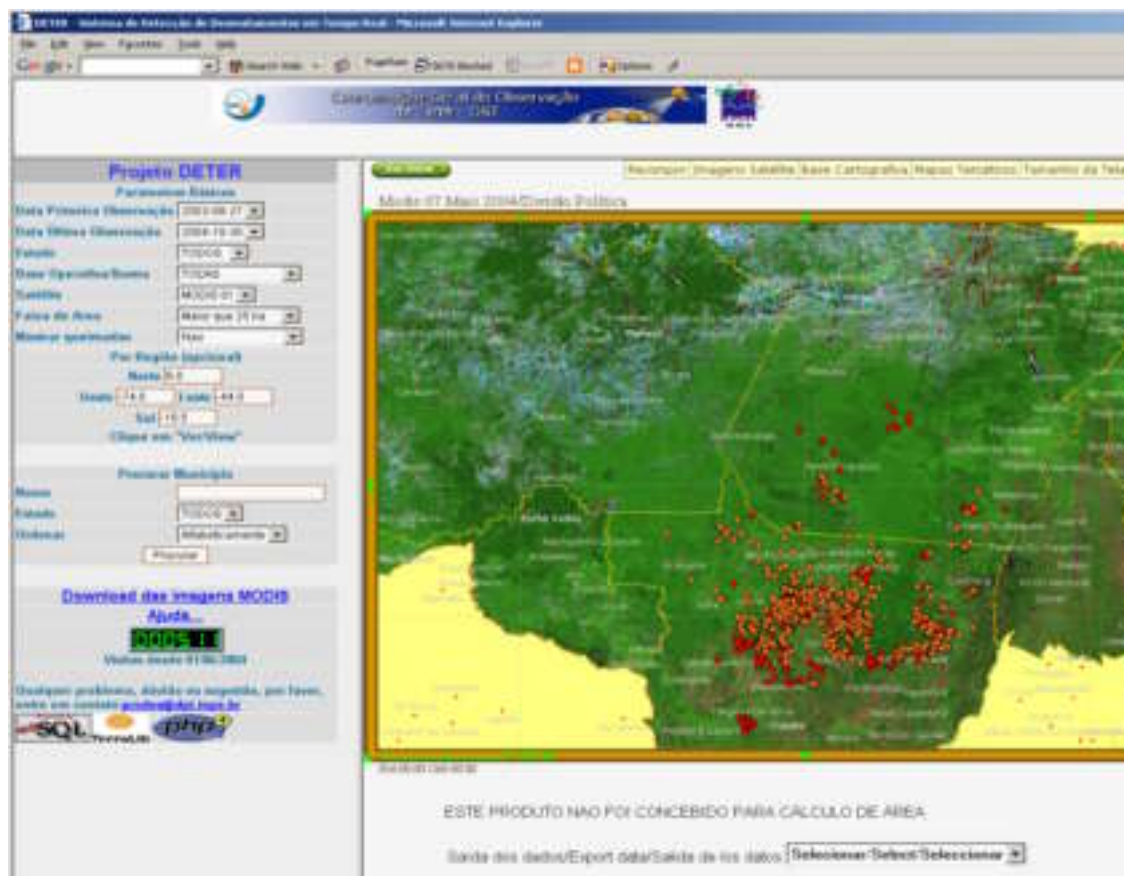
Results should be possibly verified with reference data

Coarse resolution land cover map used as ecosystem stratification





# Real-time deforestation monitoring for clearings > 25ha from coarse resolution satellite imagery



<http://www.obt.inpe.br/deter/>

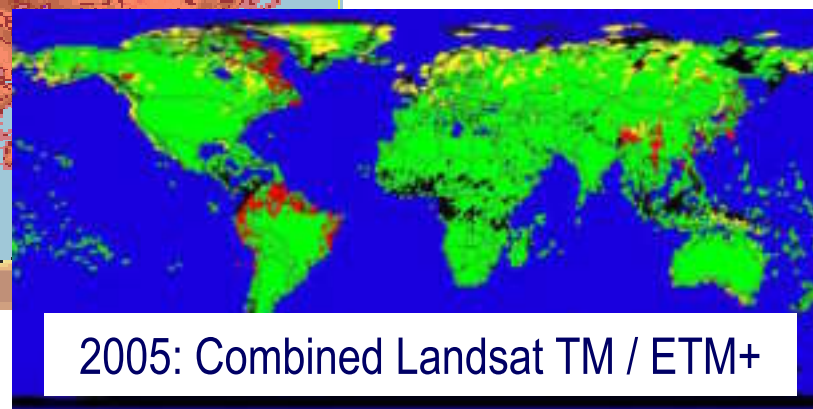
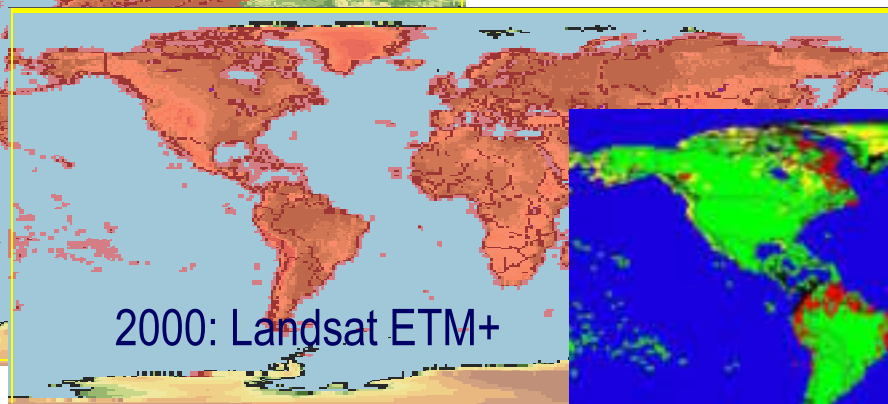
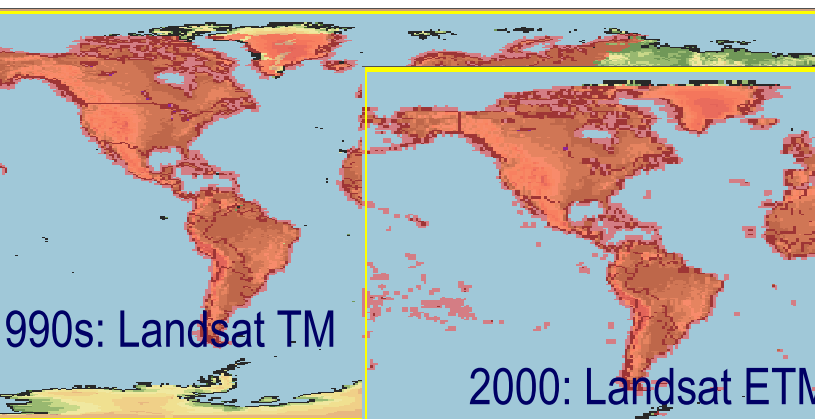
# Availability of current optical mid-resolution (10-60 m) sensors

Nation	Satellite & sensor	Resolution & coverage	Cost for data acquisition ( from archive)	Feature
A	Landsat-5 TM (since 1984)	30 m 180×180 km <sup>2</sup>	0.02 US\$/km <sup>2</sup> <b>All US archived data will become free from 2009</b>	Images every 16 days to satellite receiving station.
A	Landsat-7 ETM+ (since 1999)	30 m 60×180 km <sup>2</sup>	0.06 US\$/ km <sup>2</sup> <b>All US archived data will become free from 2009</b>	On April 2003 the failure of scan line corrector resulted in serious data quality issues
V/ Japan	Terra ASTER	15 m 60×60 km <sup>2</sup>	80 US\$/scene 0.02 US\$/km <sup>2</sup>	Data is acquired on request and not routinely collected for all areas
a	IRS-P6 LISS-III & AWIFS	23.5 & 56 m		AWIFS images can be acquired on a routine basis.
na/ Brazil	CBERS-2 HRCCD	20 m	<b>Free for developing countries</b>	Brazil uses on-demand imagery to bolster their coverage.
ria/ China/ ria/ Turkey/	DMC	32 m 160×660 km <sup>2</sup>	0.03 €/km <sup>2</sup>	Commercial; Brazil uses alongside Landsat data
nce	SPOT-5 HRVIR	5-20 m 60×60 km <sup>2</sup>	0.5 €/km <sup>2</sup>	Commercial Indonesia & Thailand used alongside Landsat data



## Availability of free global Landsat historical imagery for years 1990, 2000 and 2005

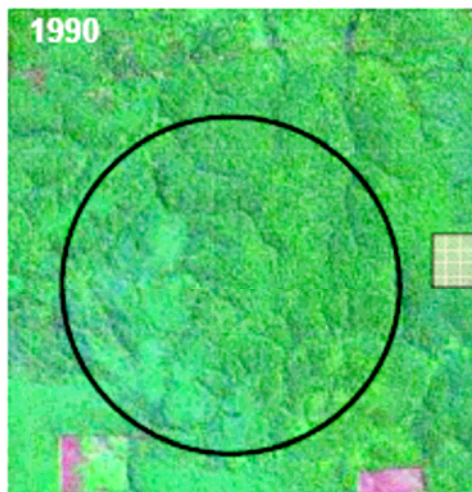
- Global Landsat mosaics produced from NASA / USGS
  - available for around-years 1990 and 2000
  - in production for 2005/2006 (due end of 2008)



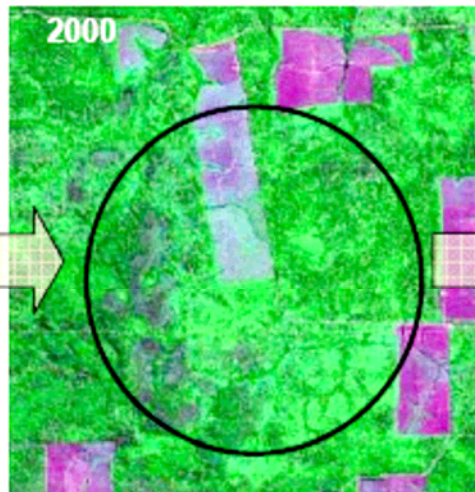
## Examples of national operational forest cover monitoring systems using satellite imagery

- Brazilian PRODES annual surveys by INPE
- Indian biennial surveys by FSI

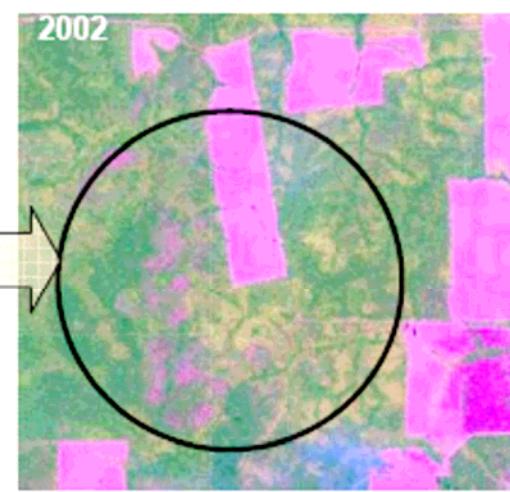
# PRODES: Annual monitoring of gross deforestation since 1988



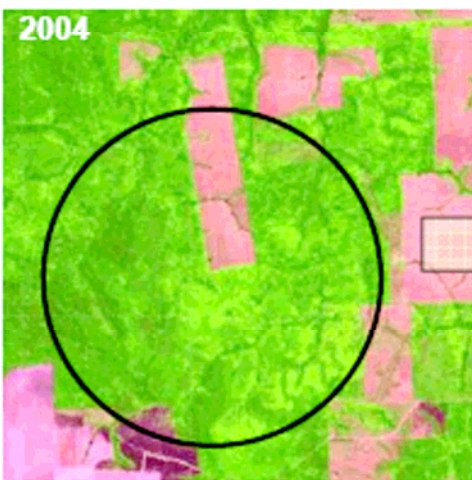
T0 Floresta



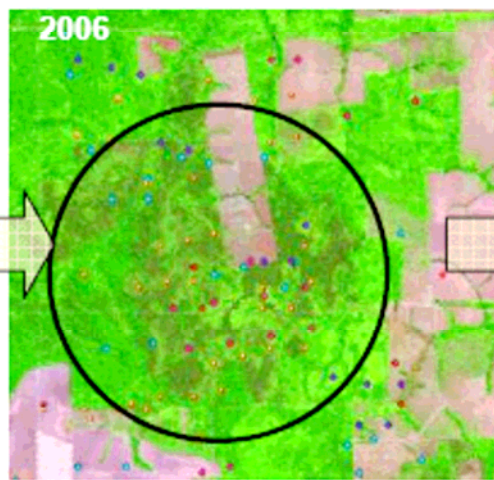
T1 Indício de degradação



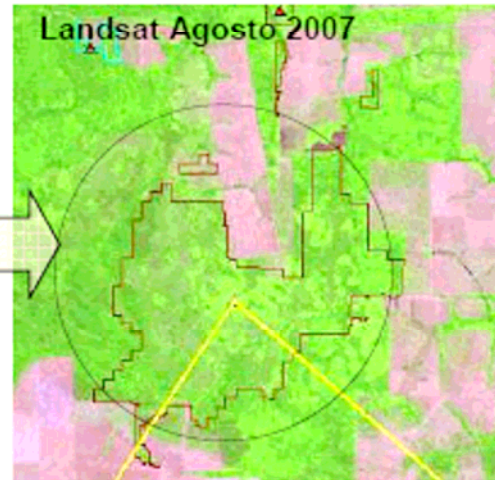
T2 Cicatriz de Fogo



T3 Indício de Degradação



T4 Focos de calor (2006)  
+ Alerta DETER

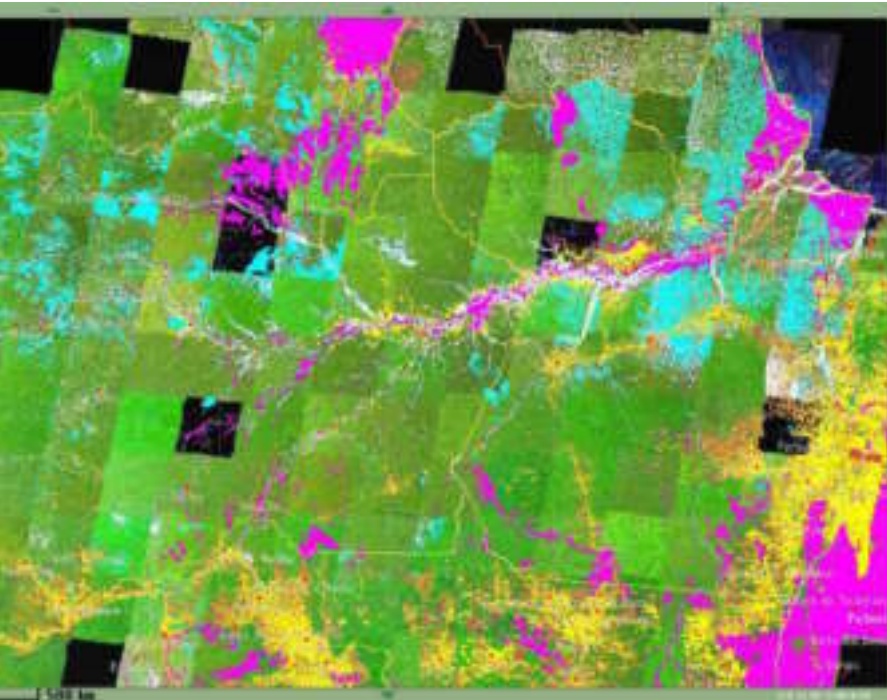


T5 Indício de degradação -  
Alerta nov/2007

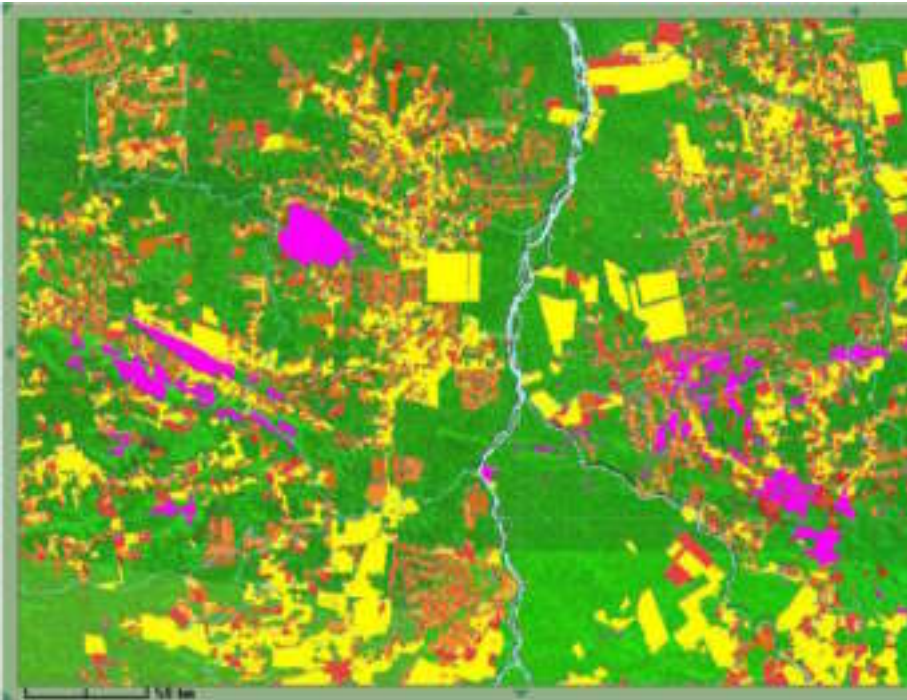


## The PRODES system :

### Annual maps of gross deforestation for Brazilian Amazonia



*Brazilian Amazon window*

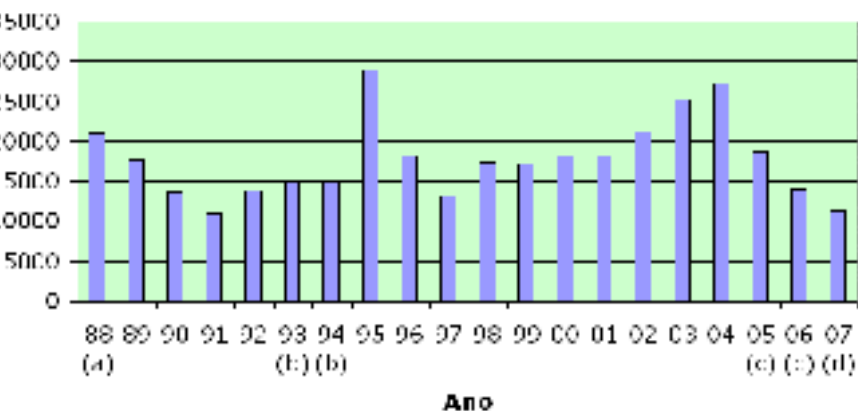


*Zoom on Mato Grosso*

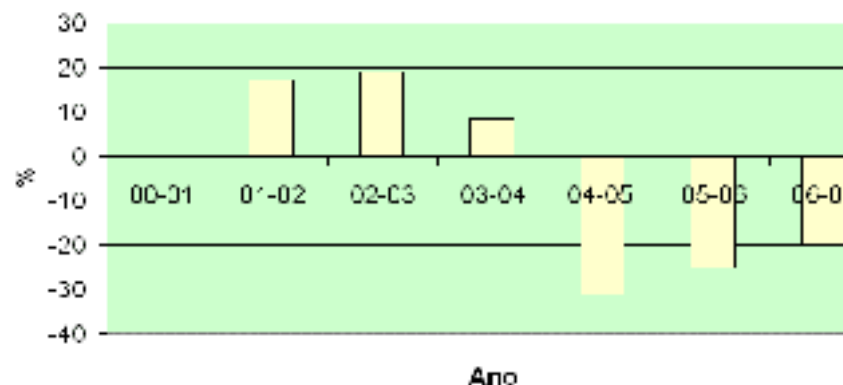
andsat satellite mosaic of year 2006 with deforestation during period 2000-200

# The PRODES monitoring system: Annual gross deforestation rates ( km<sup>2</sup>/year) and yearly variations (%/year)

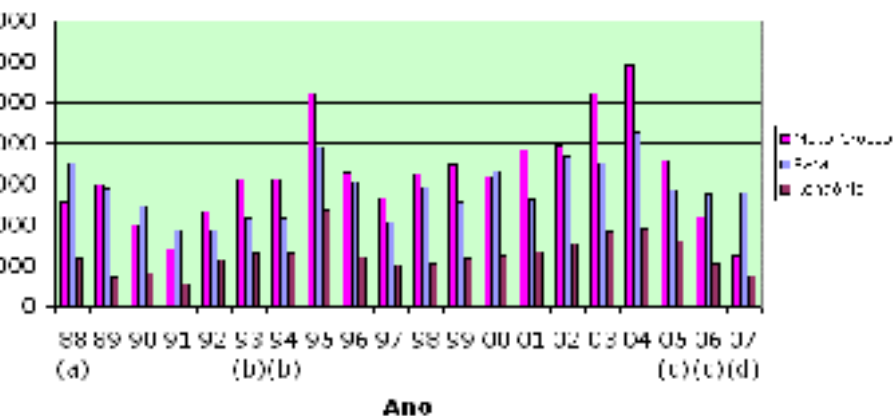
**Taxa de Desmatamento Anual na Amazônia Legal**



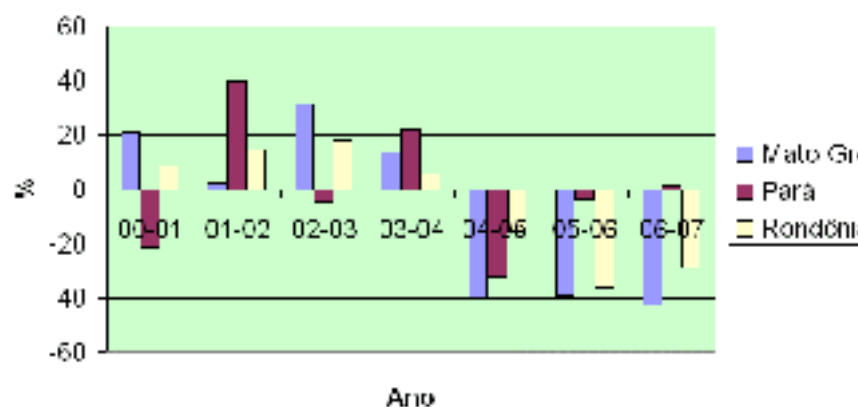
**Desmatamento na Amazônia Legal: Variação Relativa**



**Taxa de Desmatamento Anual em MT, PA e RO**



**Desmatamento: Variação Relativa**



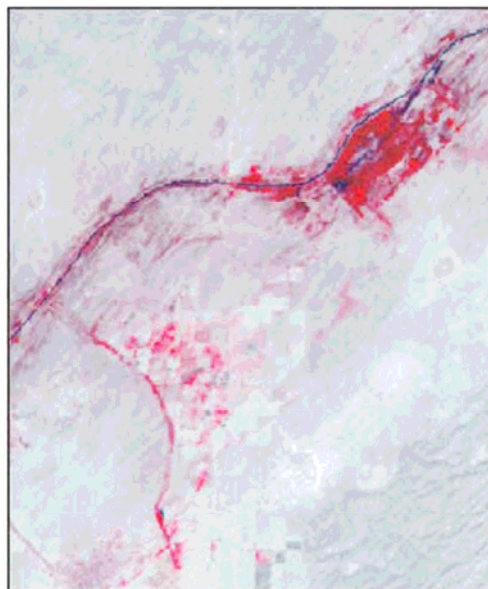
# Biennial Forest assessments from Forest Survey of India with Remote Sensing Surveys since 1981

Assessment	Period	Satellite & Sensor	Resolution	Scale	Analysis	Forest Cover million ha
I	1981-83	LANDSAT-MSS	80 m	1:1 million	visual	<b>64.08</b>
II	1985-87	LANDSAT-TM	30 m	1:250,000	visual	<b>63.88</b>
III	1987-89	LANDSAT-TM	30 m	1:250,000	Visual	<b>63.94</b>
IV	1989-91	LANDSAT-TM	30 m	1:250,000	Visual	<b>63.94</b>
V	<b>1991-93</b>	<b>IRS-1B LISSII</b>	<b>36.2 m</b>	1:250,000	<b>Visual</b>	<b>63.89</b>
VI	1993-95	IRS-1B LISSII	36.2 m	1:250,000	Visual	<b>63.34</b>
VII	1996-98	IRS-1C/1D LISS III	23.5 m	1:250,000	digital/ visual	<b>63.73</b>
VIII	<b>2000</b>	IRS-1C/1D LISS III	<b>23.5 m</b>	1:50,000	<b>digital</b>	<b>65.38</b>
IX	2002	IRS-1D LISS III	23.5 m	1:50,000	digital	<b>67.78</b>
X	2004	IRS P6- LISS III	23.5 m	1:50,000	digital	<b>67.70</b>

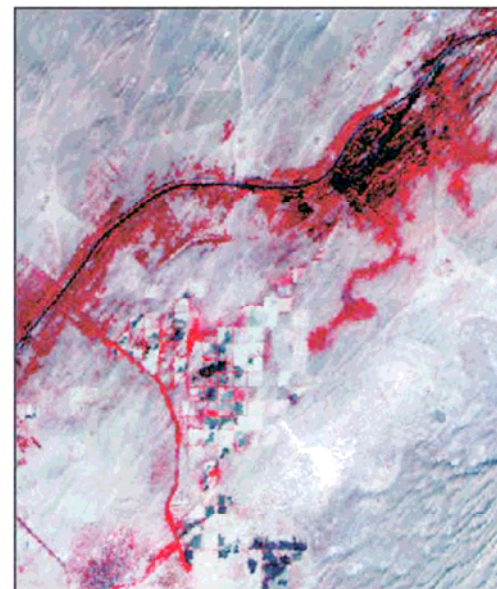




State of Forest report 2005

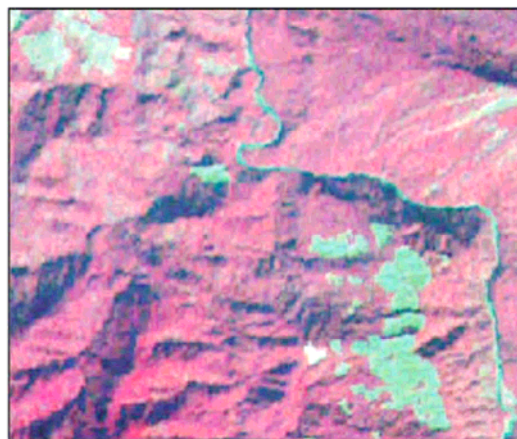


2003



2005

Plantations along Indira Gandhi Canal, Ganganagar, Rajasthan



2003



2005

Regrowth in abandoned shifting cultivation area in Aizawl, Mizoram

### Main Characteristics of biennial Remote Sensing Survey

- Minimum mapping Unit = 1 ha
- 3 forest cover classes, Shrub class, non-forest class
- Image interpretation complemented by extensive field verification
- Accuracy of the 2005 assessment has been found to be 92 %

Very Dense Forest	All lands with tree cover of canopy density of 70% and above
Moderately Dense Forest	All lands with tree cover of canopy density between 40 % and 70 % above
Open Forest	All lands with tree cover of canopy density between 10 – 40 %.
Scrub	All forest lands with poor tree growth mainly of small or stunted trees having canopy density less than 10 percent.
Non-forest	Any area not included in the above classes.