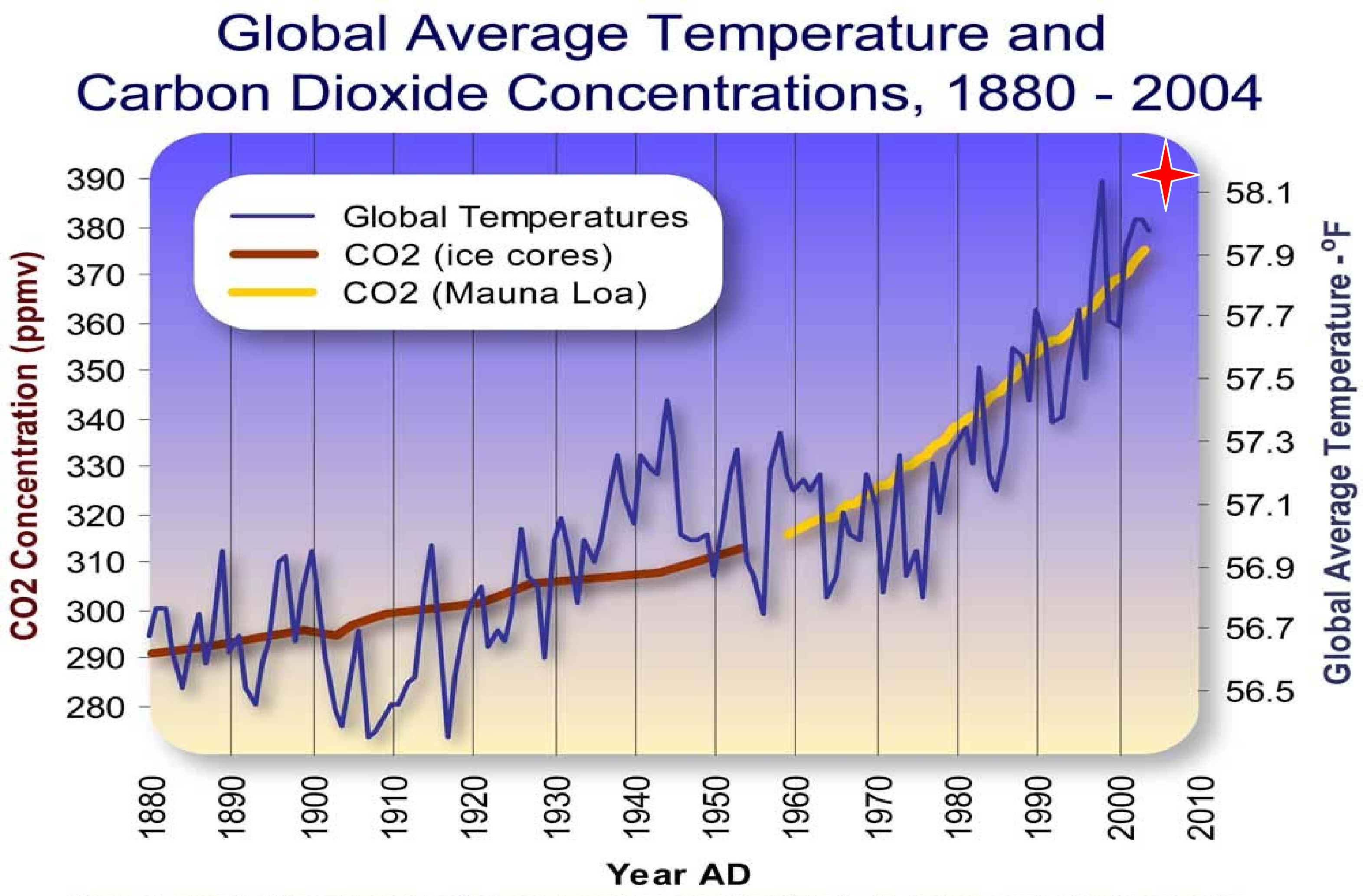
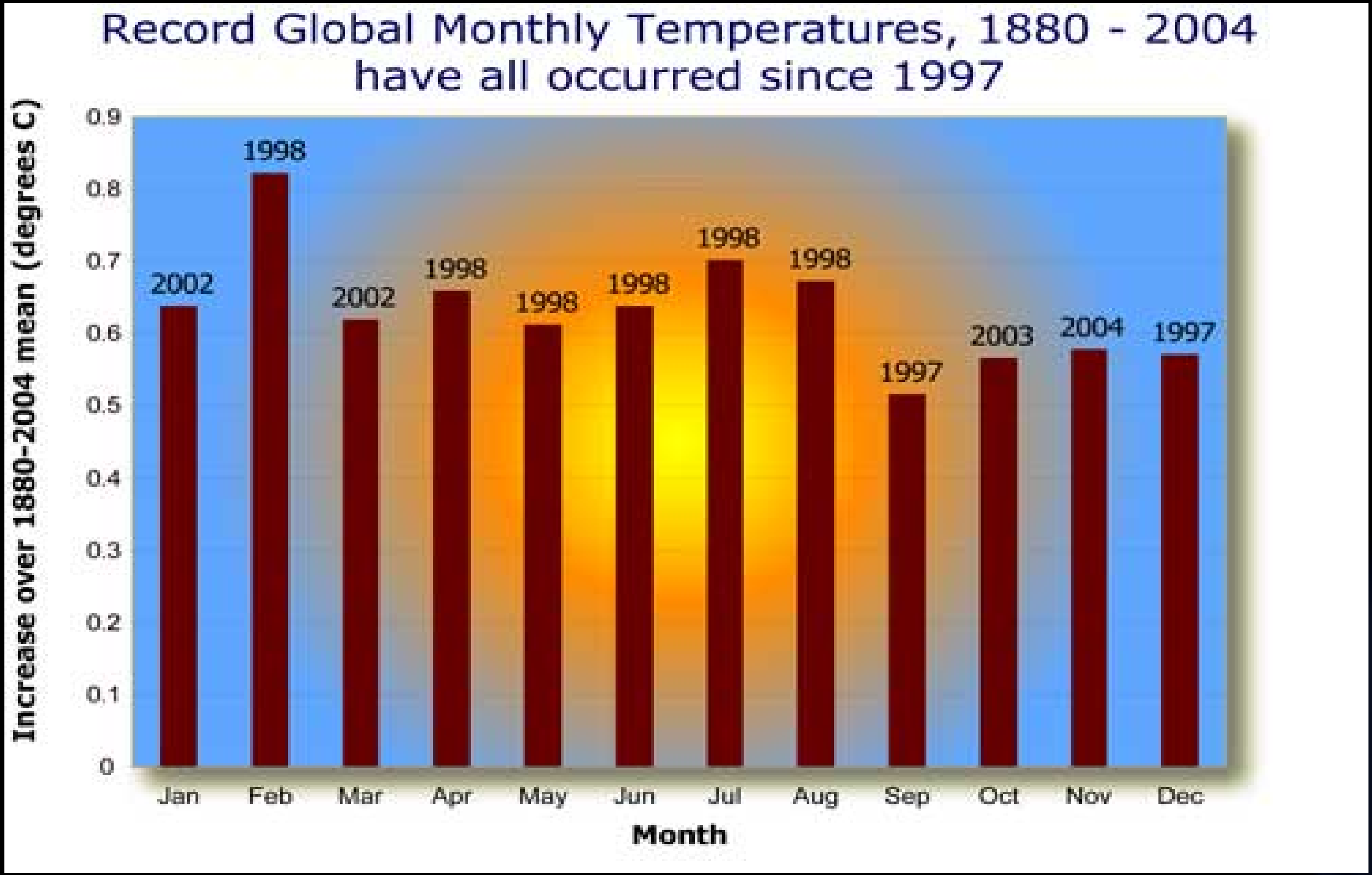
Global Deforestation

David L. Skole

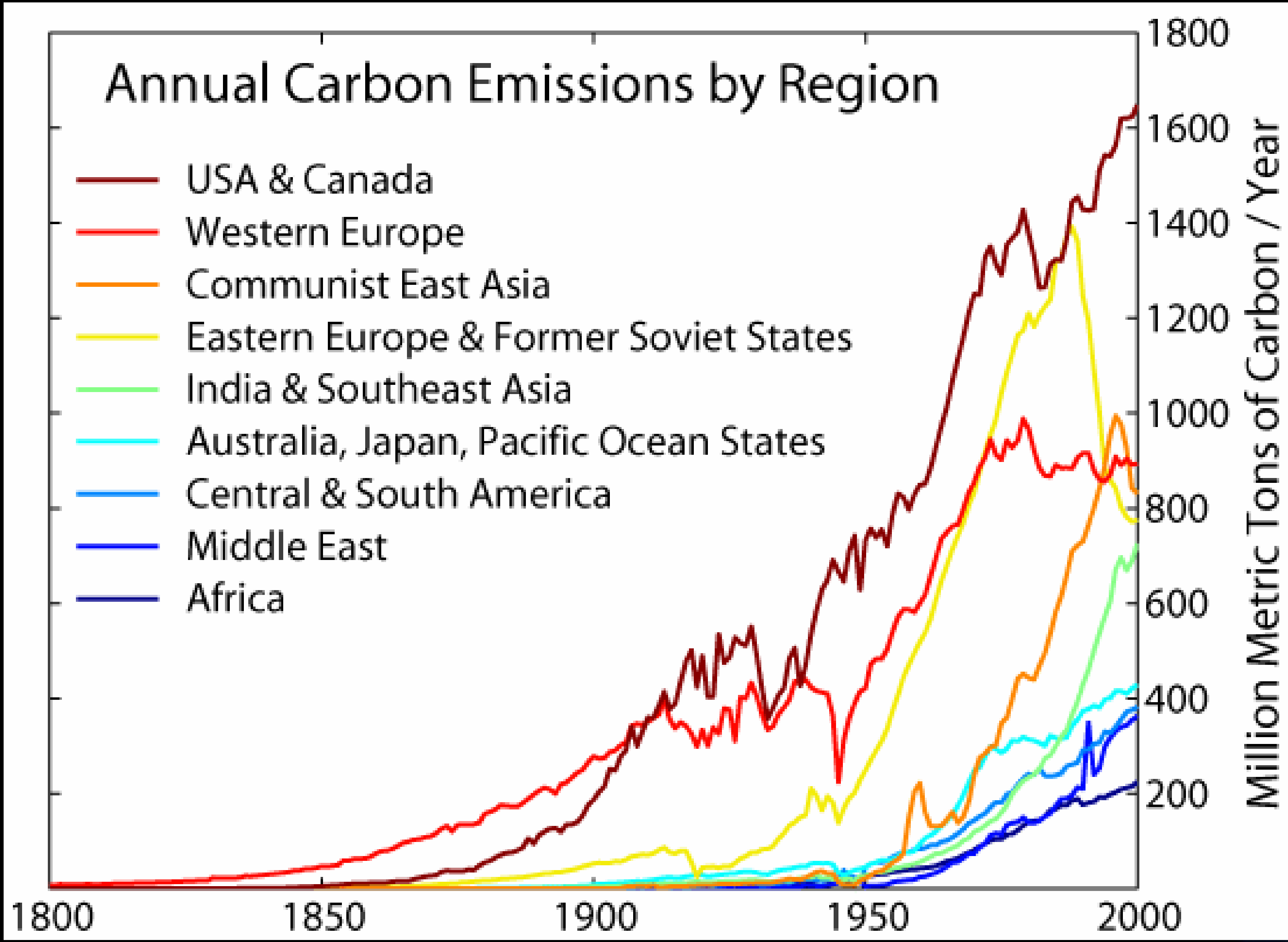

Global Average Temperature and
Carbon Dioxide Concentrations, 1880 - 2004
Global Temperatures
CO2 (ice cores)
CO2 (Mauna Loa)
CO2 Concentration (ppmv)
390
380
370
360
350
340
330
320
310
300
290
280
Global Average Temperature - °F
58.1
57.9
57.7
57.5
57.3
57.1
56.9
56.7
56.5
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year AD



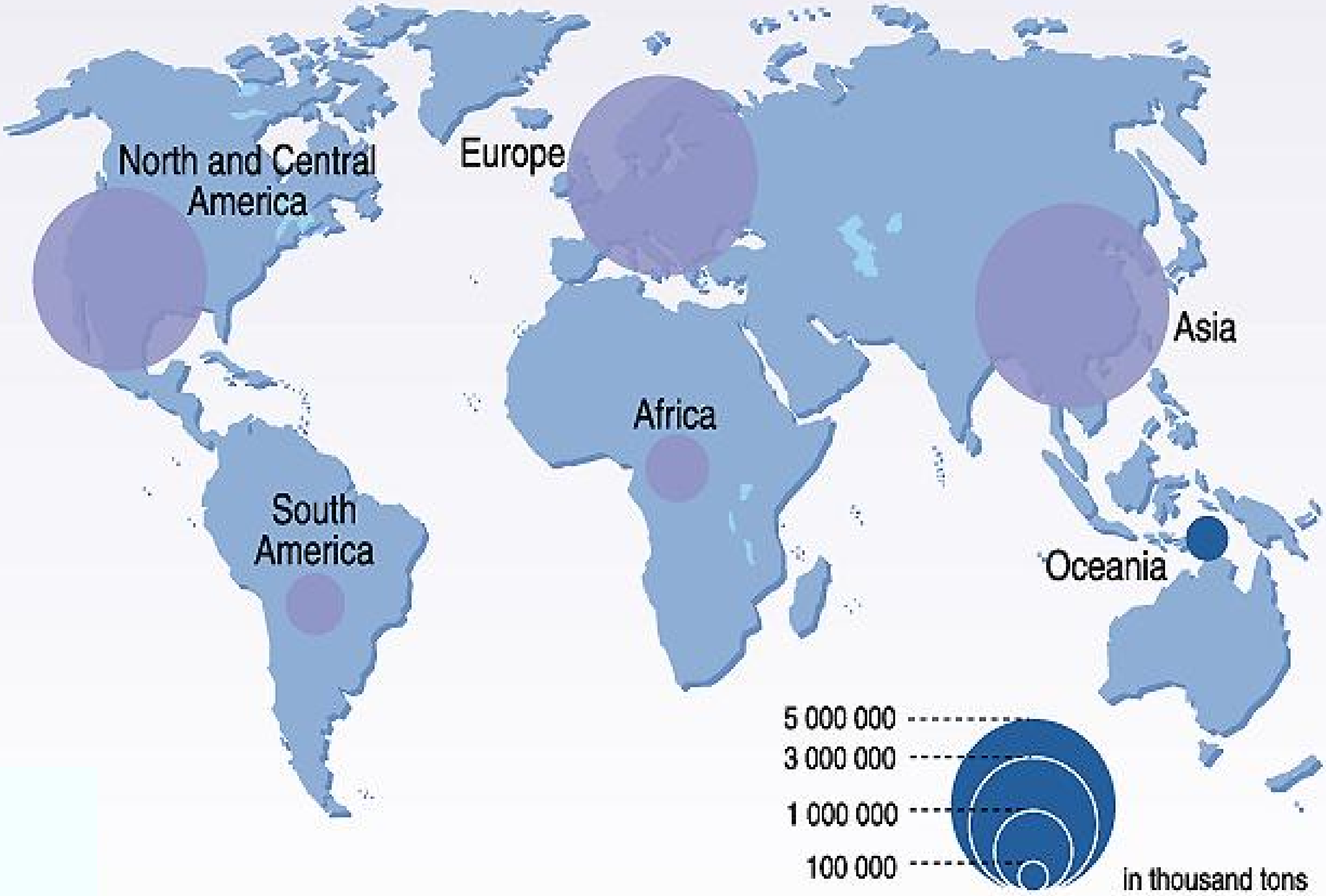
Record Global Monthly Temperatures, 1880 - 2004
have all occurred since 1997
Increase over 1880-2004 mean (degrees C)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2002
1998
2002
1998
1998
1998
1998
1998
1997
2003
2004
1997
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Significance

- New studies show an increase in temperature by 1º C will decrease rice (Asia, Africa) and soybeans (North America, Latin America) by 11-17%
  - *A decade of agricultural research wiped out*

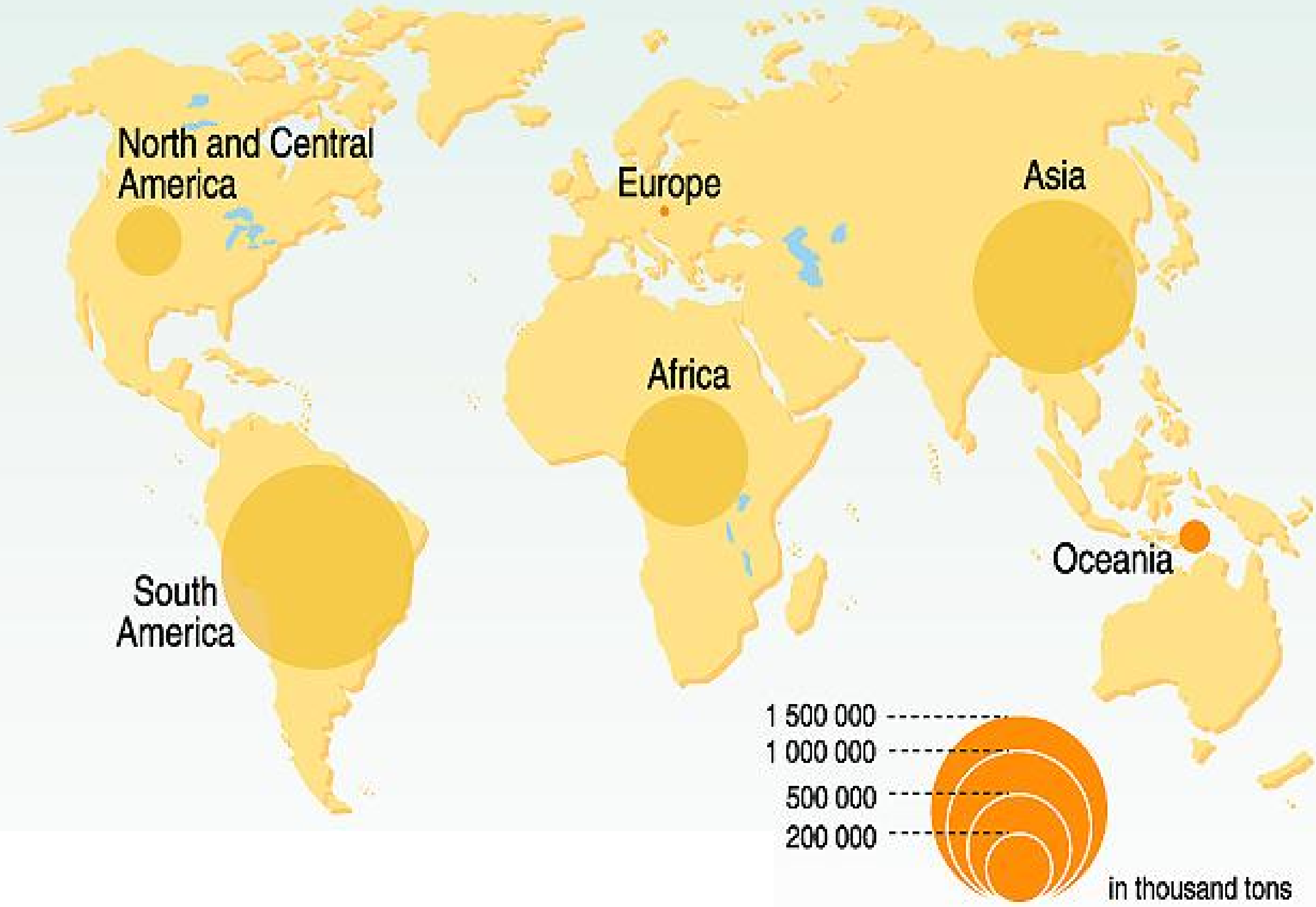

Annual Carbon Emissions by Region
USA & Canada
Western Europe
Communist East Asia
Eastern Europe & Former Soviet States
India & Southeast Asia
Australia, Japan, Pacific Ocean States
Central & South America
Middle East
Africa
1800
1600
1400
1200
1000
800
600
400
200
Million Metric Tons of Carbon / Year
1800
1850
1900
1950
2000

CO_2 emissions from industrial processes



Source: United Nations framework convention on climate change (UNFCCC).

CO_2 emissions from land use change



Source : Climate Change Information kit, UNEP IUC, 1997.

Global Emissions from Land Use Change

Historically

Total emissions of C

[deforestation and fossil-fuel burning]

450 PgC

[180-200 PgC from land use change]

+ 90 ppm CO_2 in the atmosphere

[40 ppm due to changes in land use]

From 1850 to 2000

124 Pg emitted due to land use change

60% in tropical areas

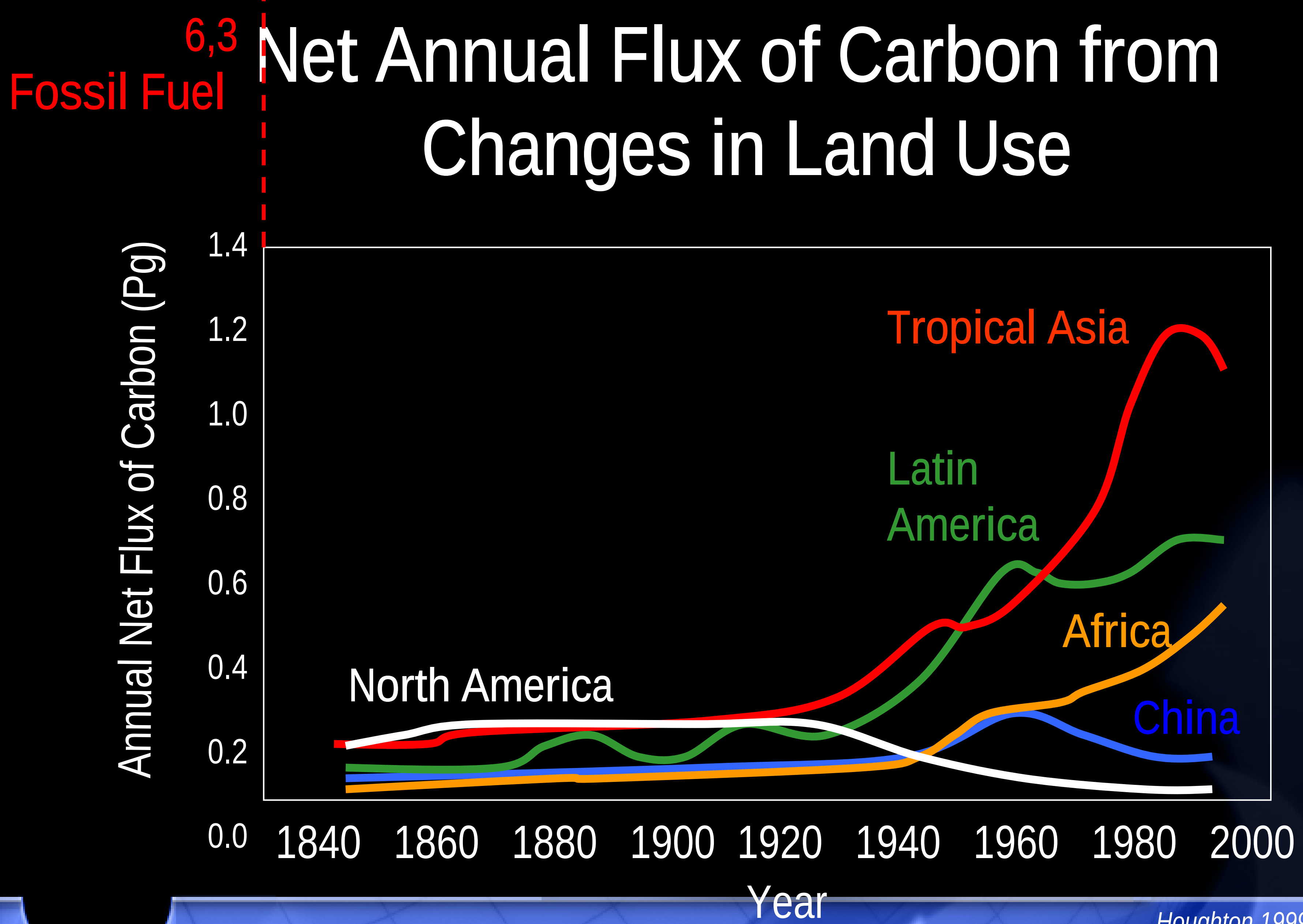
%40 in temperate areas

90% due to deforestation

[20% descrease Forest Area]

Houghton et al. 1999, Houghton 1999, Defries et al. 1999, IPCC-TAR 2001

Net Annual Flux of Carbon from Changes in Land Use



Houghton 1999

Global Carbon Budget - The fate of CO_2

Period 1990-1996

7.9 Pg C/yr
(6.3 Pg Fossil Fuel)
(1.6 Pg Land Use)

3.7 PgC/yr - Atmosphere

2.9 PgC/yr - Oceans

1.3 PgC/yr - Terrestrial Ecosystems

After IPCC, TAR 2001

Current Terrestrial Sinks

Potential Driving Mechanisms

- CO_2 fertilization
- Nitrogen fertilization
- Climate change

Land Use/Cover Change

- Regrowth of previously harvested forests
  - Reforestation / Afforestation
- Regrowth of previously disturbed forests
  - Fire, wind, insects
- Fire suppression
- Decreased deforestation
- Improved agriculture
- Sediment burial
- Future: Terrestrial Carbon Management (e.g., Kyoto)

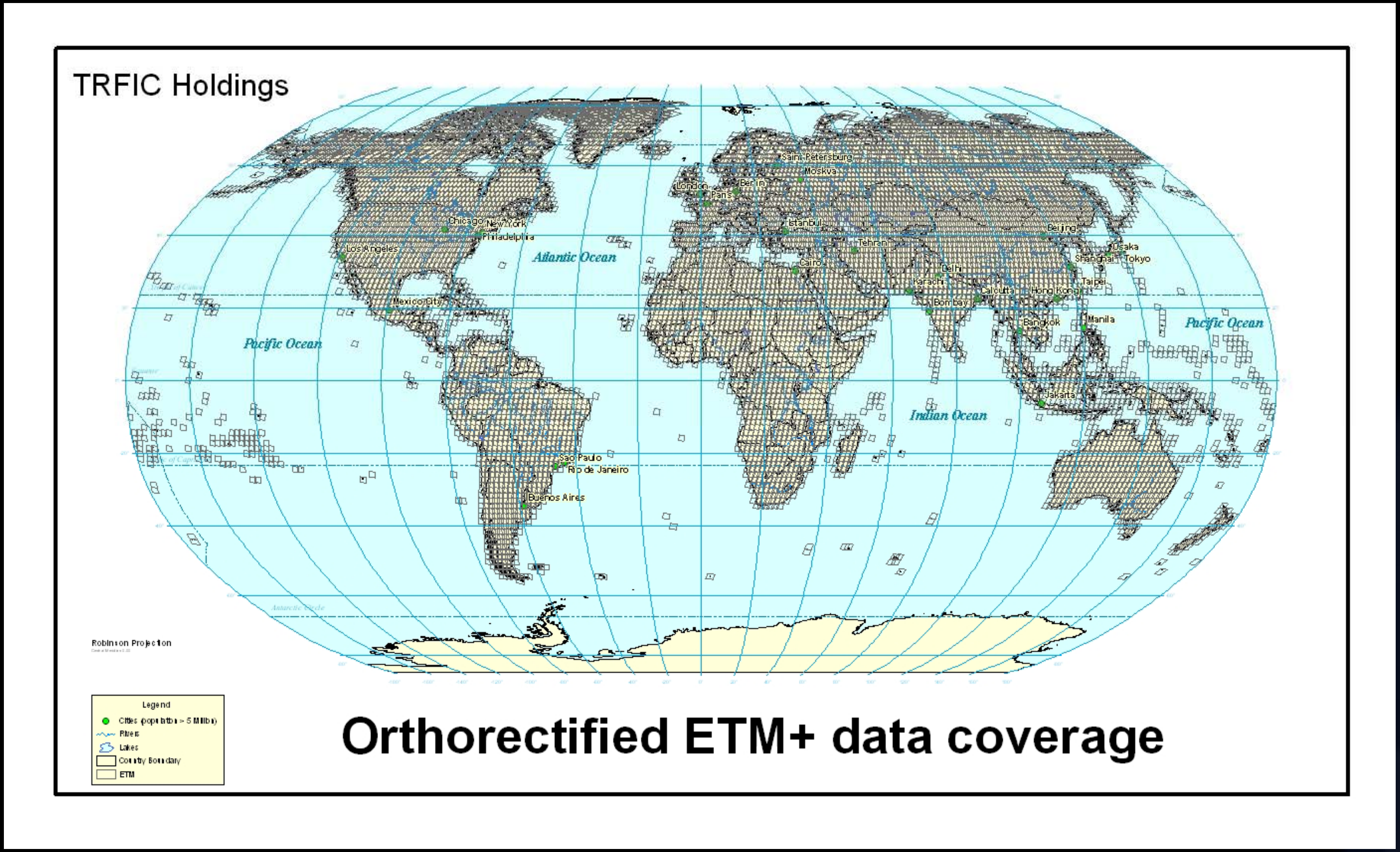
Global rates are uncertain

- Samples from hot spots or other measures inadequate
- Incomplete picture without degradation
  - May be important only for certain places and certain time periods
- Different definitions and methods result in differing claims

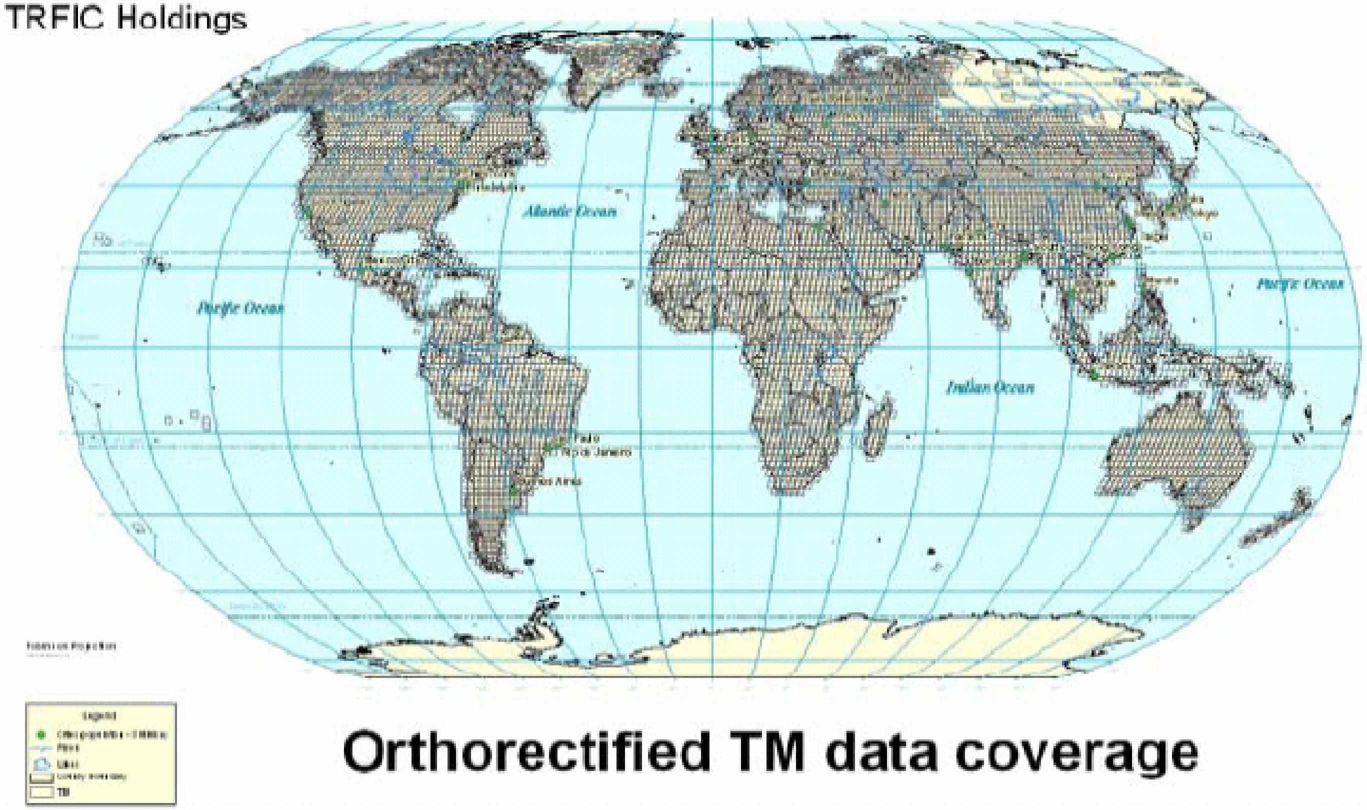
What we think we know

- Global rates continue to increase but not as fast as earlier decades
- Areas of most rapid change are not the “traditional” cover story places
  – The Amazon and logging: logging is only recently important
  – Southeast Asia has significant changes for a smaller region
- Some areas are experiencing net forest area increases

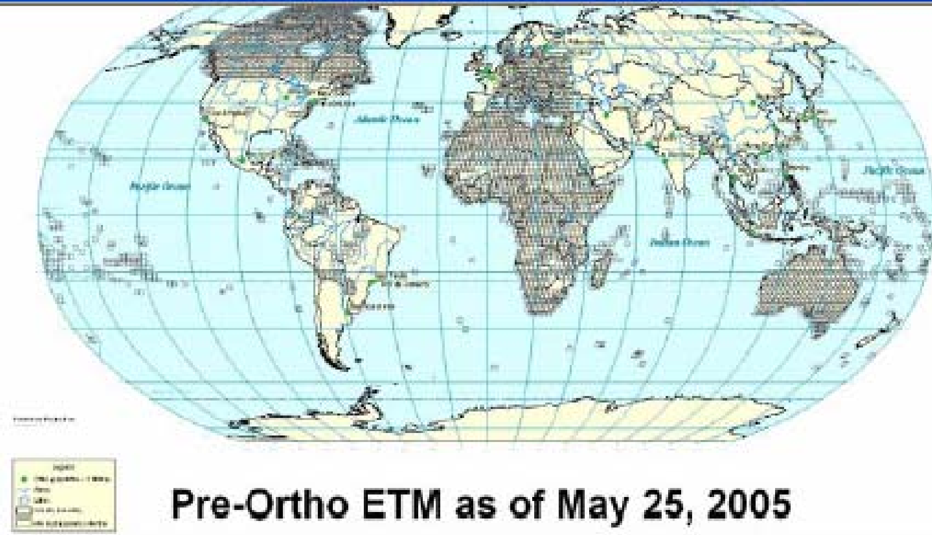
Product overviews



TRFIC Holdings

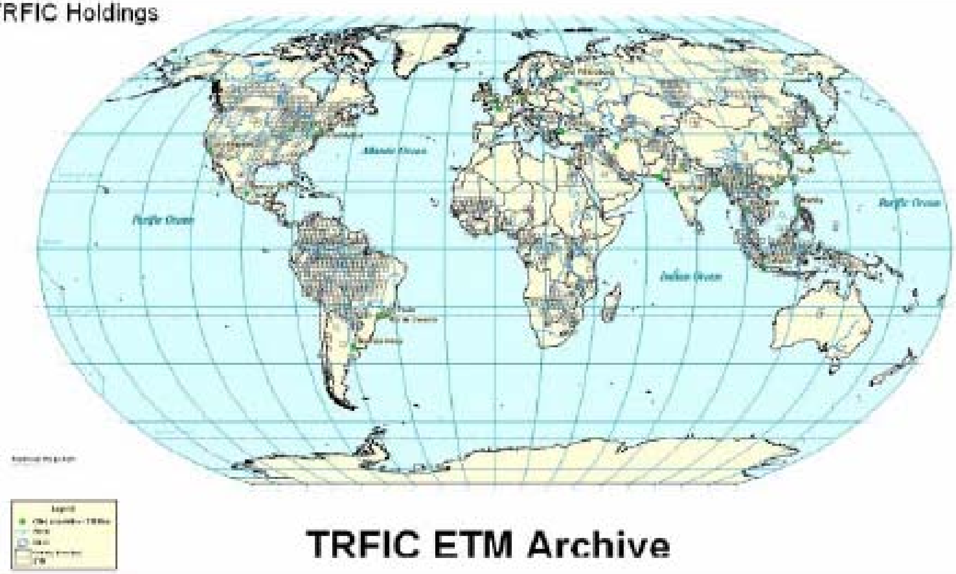


Orthorectified TM data coverage



Pre-Ortho ETM as of May 25, 2005

TRFIC Holdings



TRFIC ETM Archive

Table 3: Forest cover 1990 & 2000 and average annual rate of chang

	Forest 1990	Forest 2000	Change	Average Annual Rate
Cambodia	9501	8800	-701	-0.74%
Lao PDR	16990	17228	238	0.14%
Myanmar	45183	43940	-1243	-0.28%
Thailand	16540	15968	-572	-0.35%
Vietnam	9175	10915	1740	1.90%
TOTAL	**97389**	**96851**	**-538**	**-0.06%**

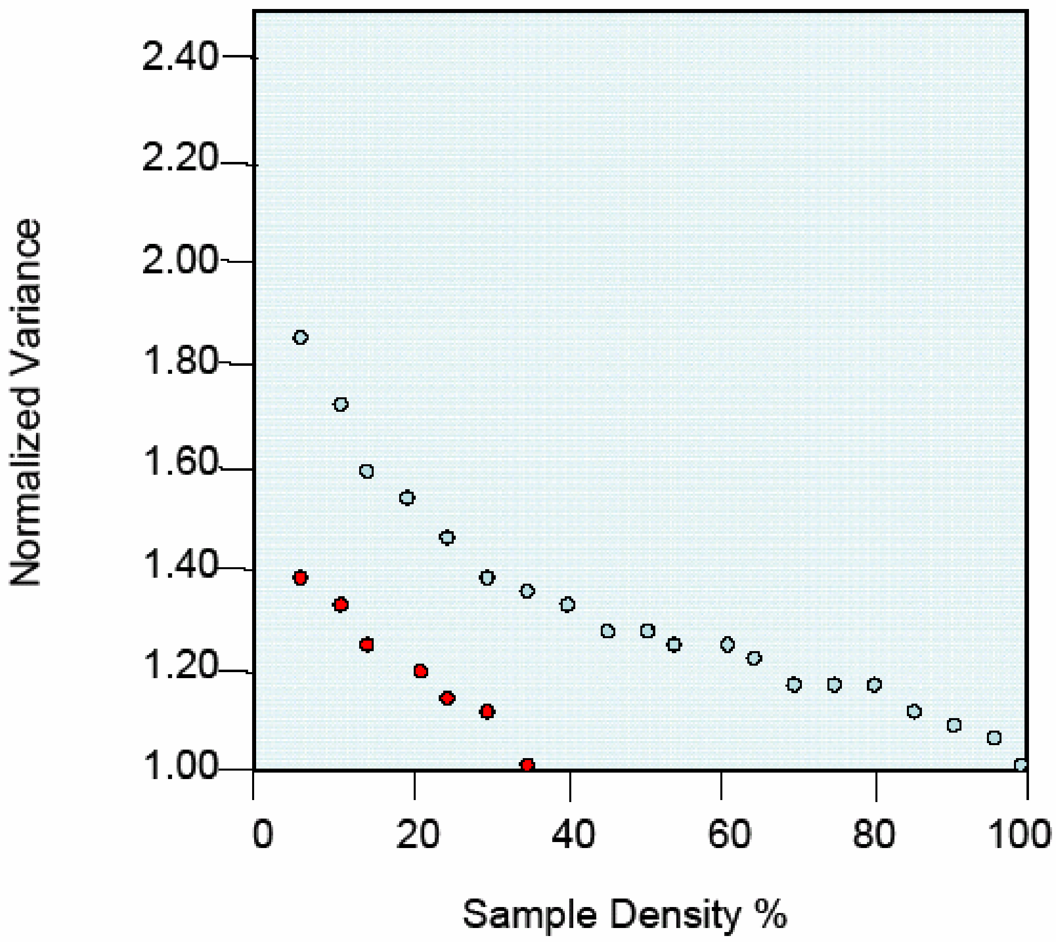
Area in 1000 ha

Table 2: Average annual forest cover change rates 1990 - 2000

	Mongabay.com^	FAO FRA 2005 Country Tables On-line**	TRFIC	Average
Cambodia	-1.09%	-0.80%	-0.74%	-0.88%
Lao PDR	-0.45%	0.17%	0.14%	-0.05%
Myanmar	-0.93%	-0.63%	-0.28%	-0.61%
Thailand	-1.19%	-0.22%	-0.35%	-0.59%
Vietnam	2.25%	1.26%	1.90%	1.80%

Why we cannot sample

- We cannot randomly sample at low sample densities because
  - We have a poor understanding of the population sample distribution
  - The phenomenon is spatially clumped
  - The phenomenon of deforestation is linked to other factors



2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
Normalized Variance
0
20
40
60
80
100
Sample Density %

Main points for carbon

- Deforestation is dynamic – losses and regeneration
- Deforestation is complex – varies over time and place
- Deforestation occurs through a range of states, from very obvious clearing to subtle degradation
- Land use change leaves a mosaic of various cover types and cover states in the landscape
- These mosaics have "memory", that is manifested in long term sources, and sinks in regrowth and soil OM storage
- Changes in stocks – changes in area, changes in density -- and changes in fluxes, which vary with time

Geography and timing

- Past deforestation may currently be regenerating; in regions where current deforestation is declining and there are larger regenerating areas (reflecting a history of large deforestation rates), such asynchronies may be important.

- Considerable evidence for large areas of regeneration, and for considerably variable rates of clearing

Multiple changes in one landscape

- The current landscape is a mosaic, or record, of current and past land use and cover changes
- Variation exists at fine temporal and spatial scale
- Variation exists across classes of cover (from conversion) and within classes of cover (from modification or degradation)
- History has created a more complex landscape
- We know nothing about the processes which form this landscapes over time, nor do we have good measures (maps) of these landscapes themselves.
- Our prognostic ability is severely limited

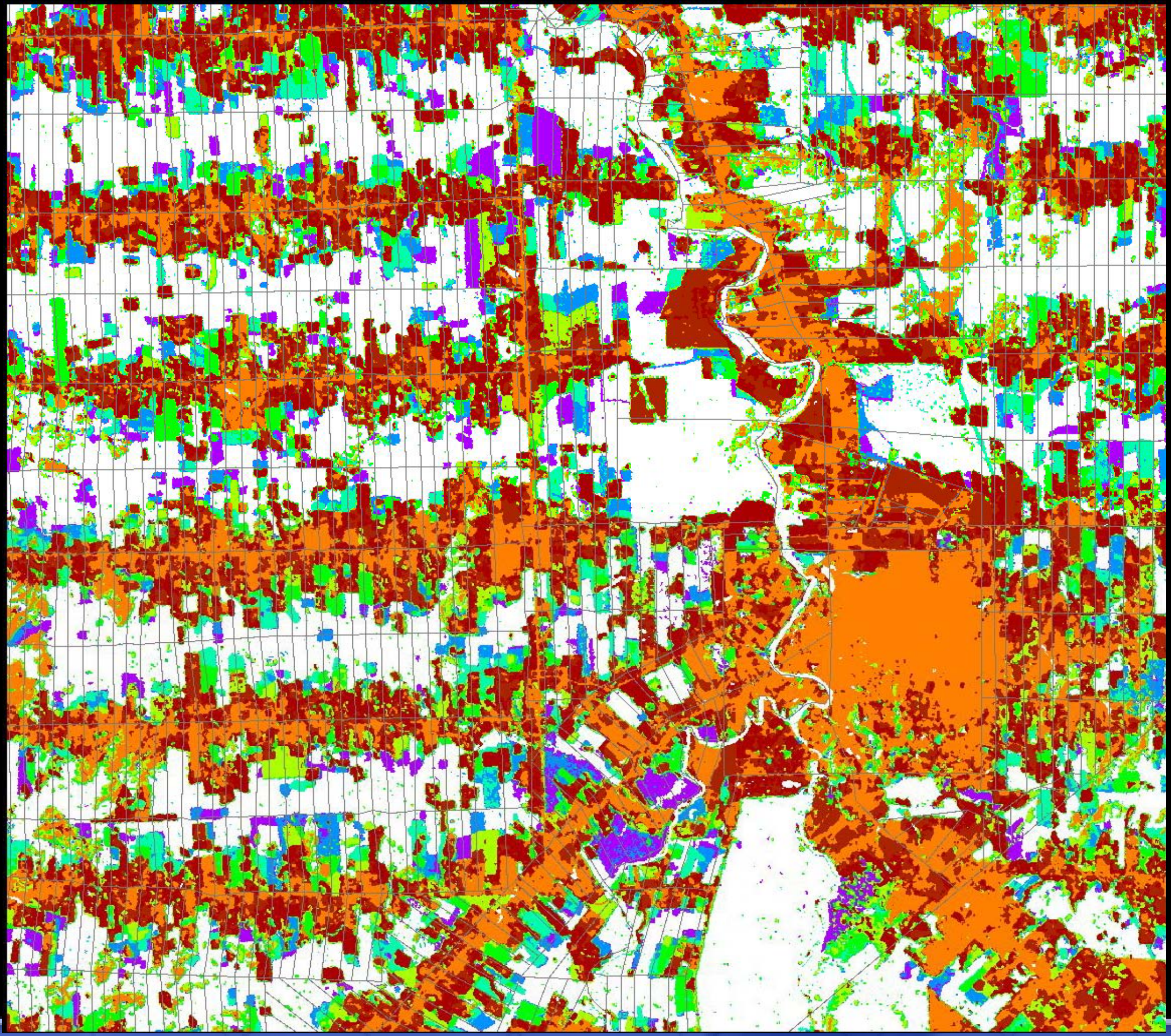
Observations: extent and density

- We can now focus on making direct observations of changes in forest ***extent*** (both increase and decrease) and ***density***

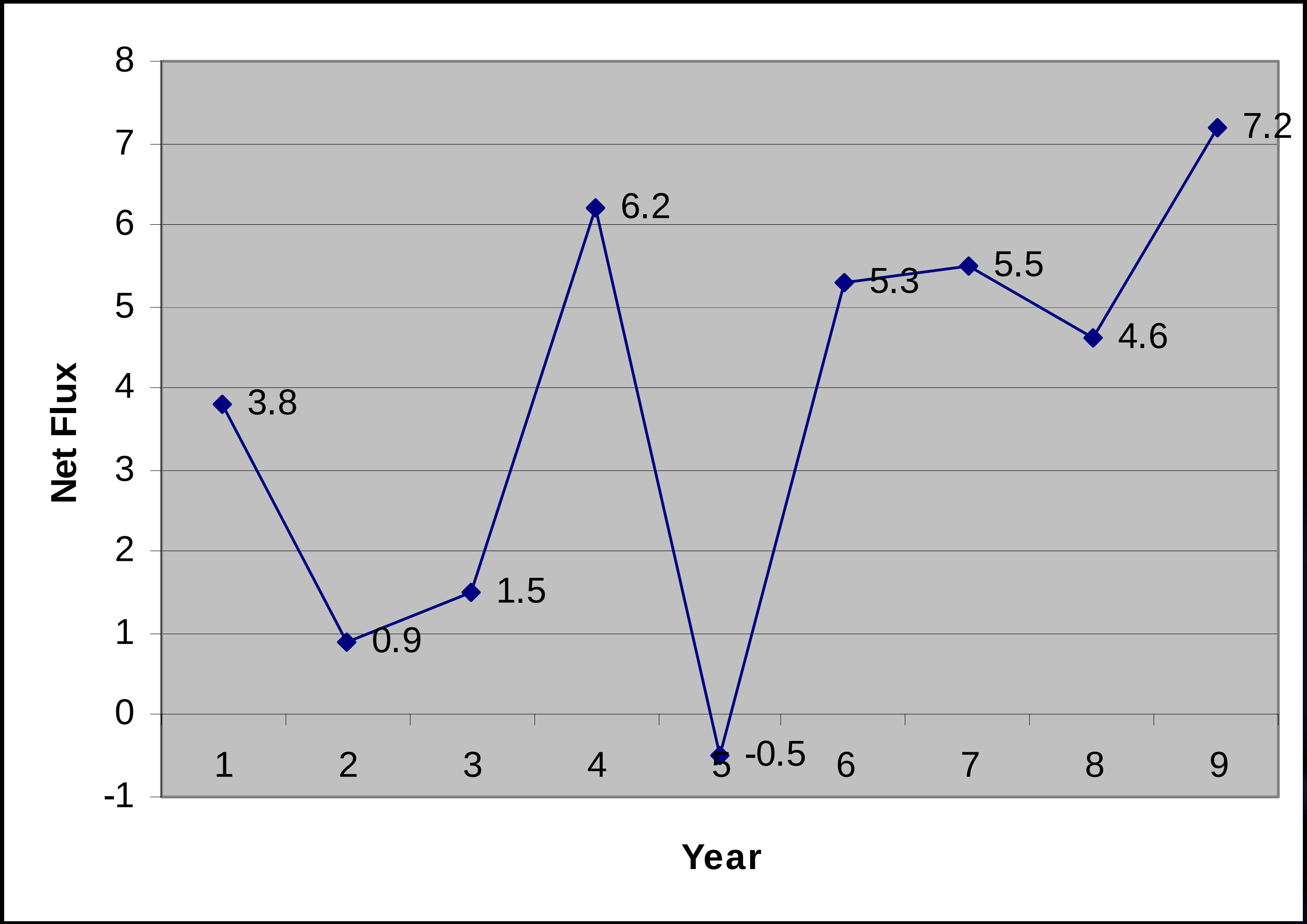
- This can be done using frequent (annual) observations from high spatial resolution remote sensing in conjunction with a coupled land use-carbon models.

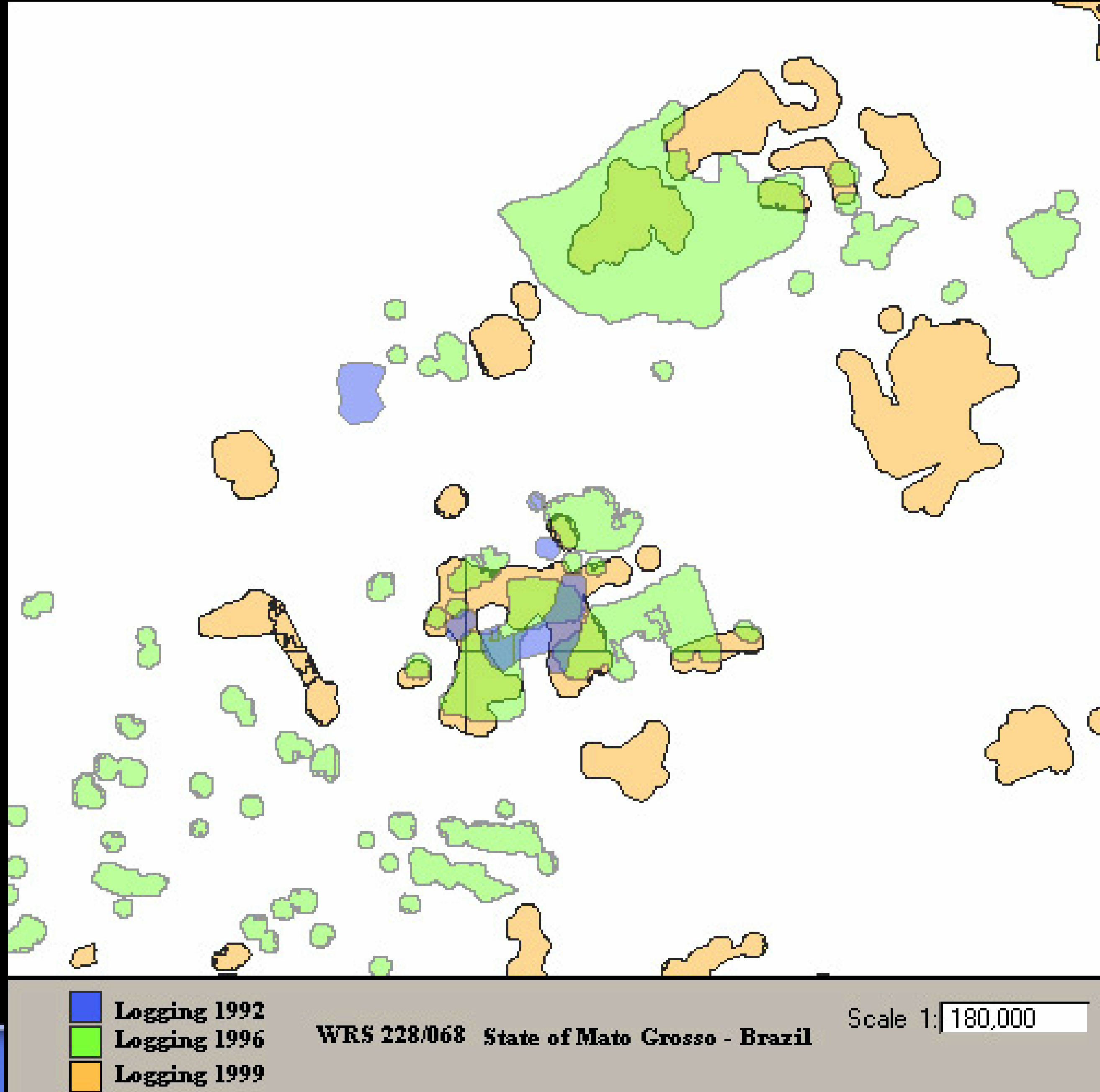
- This approach complements, but is more direct in determining the land use component, than use of other measures of changes in forest carbon from stand inventory data alone (Casperson et al. 2000)

Carbon flux over space

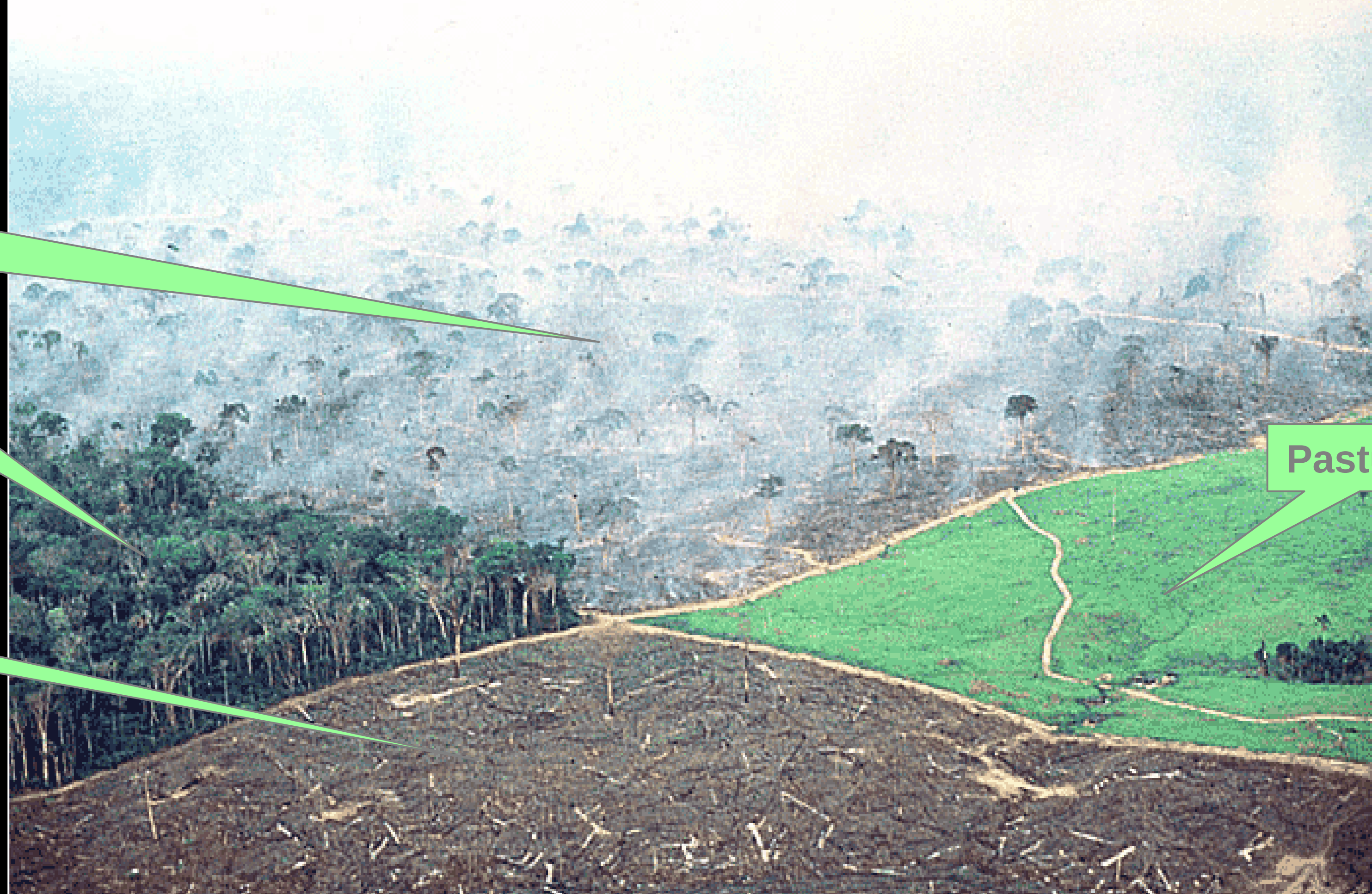


Carbon flux over time




Logging 1992
Logging 1996
Logging 1999
WRS 228/068 State of Mato Grosso - Brazil
Scale 1: 180,000

Background: (deforestation)



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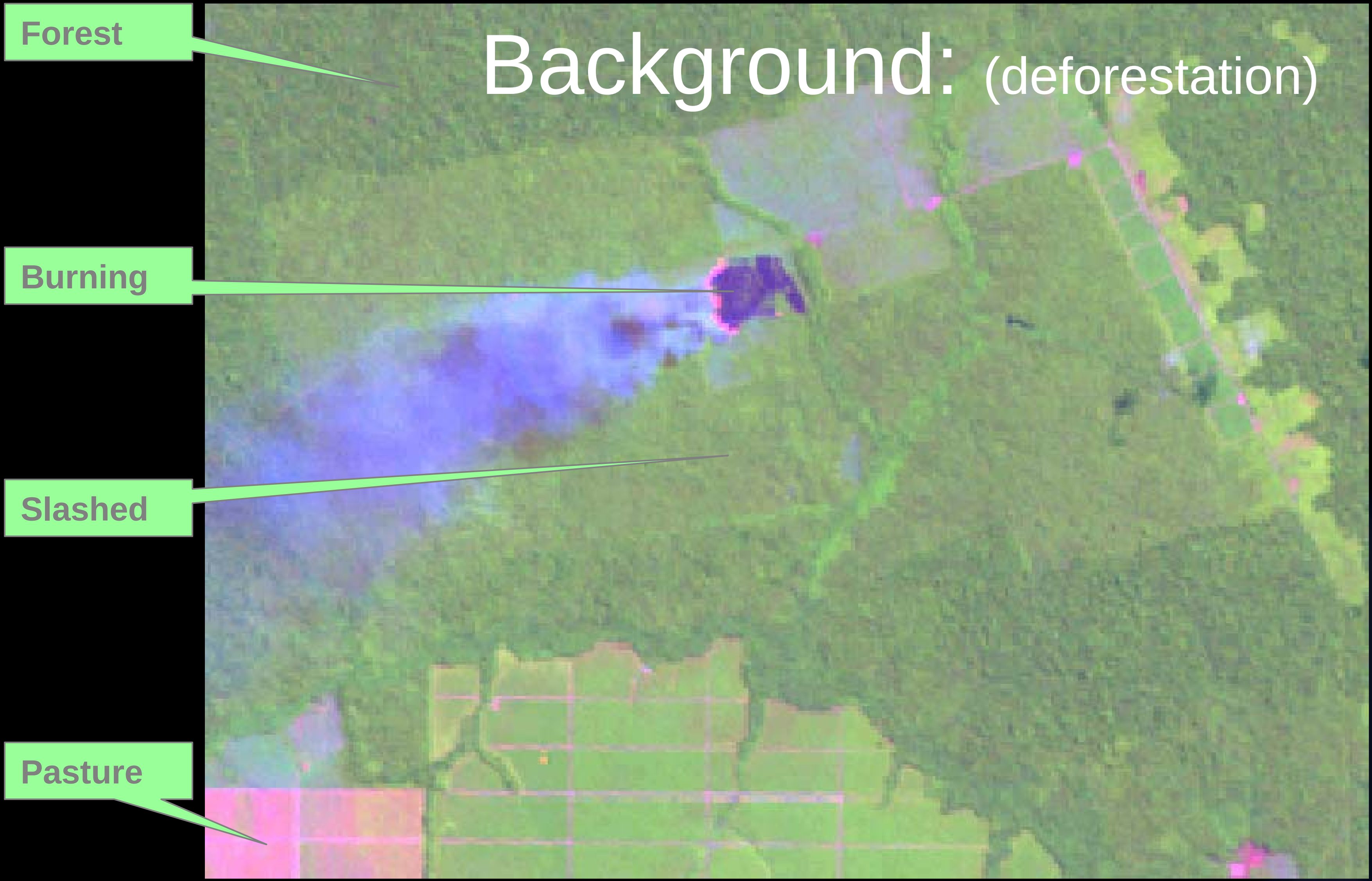


Landsat ETM+, RGB 5/4/3 – 230/069 - 2000

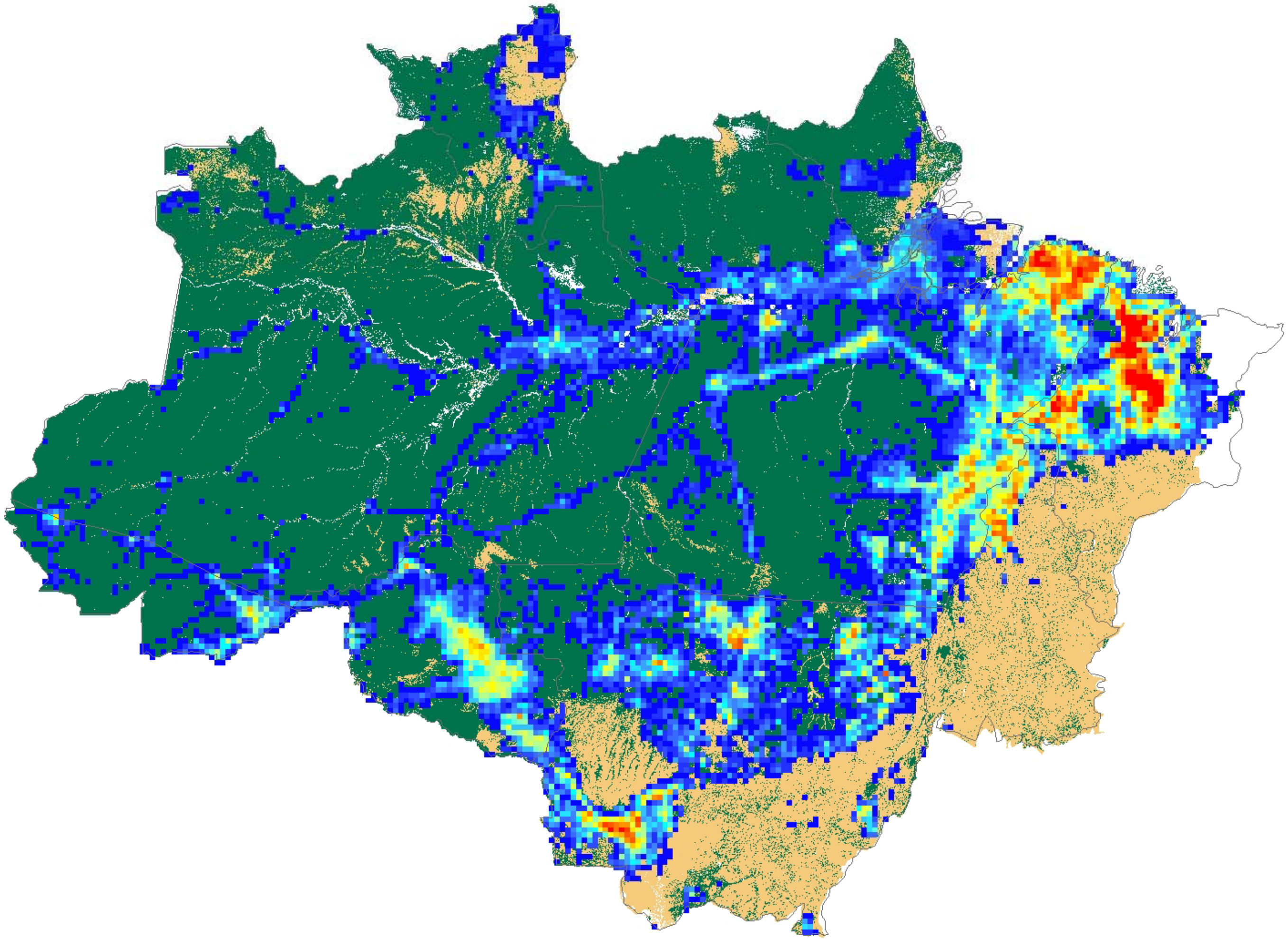
(selective logging)

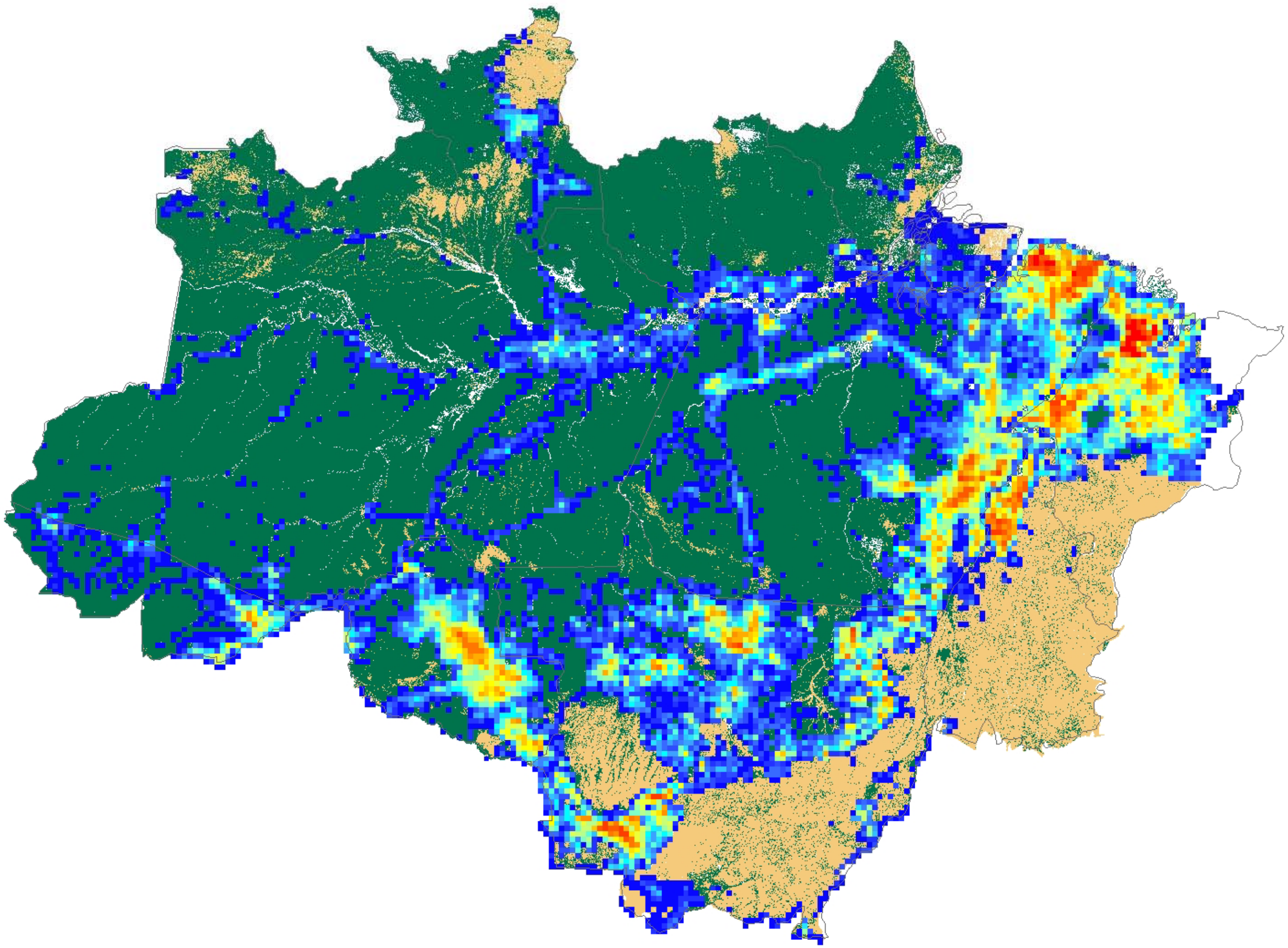
(selective logging)

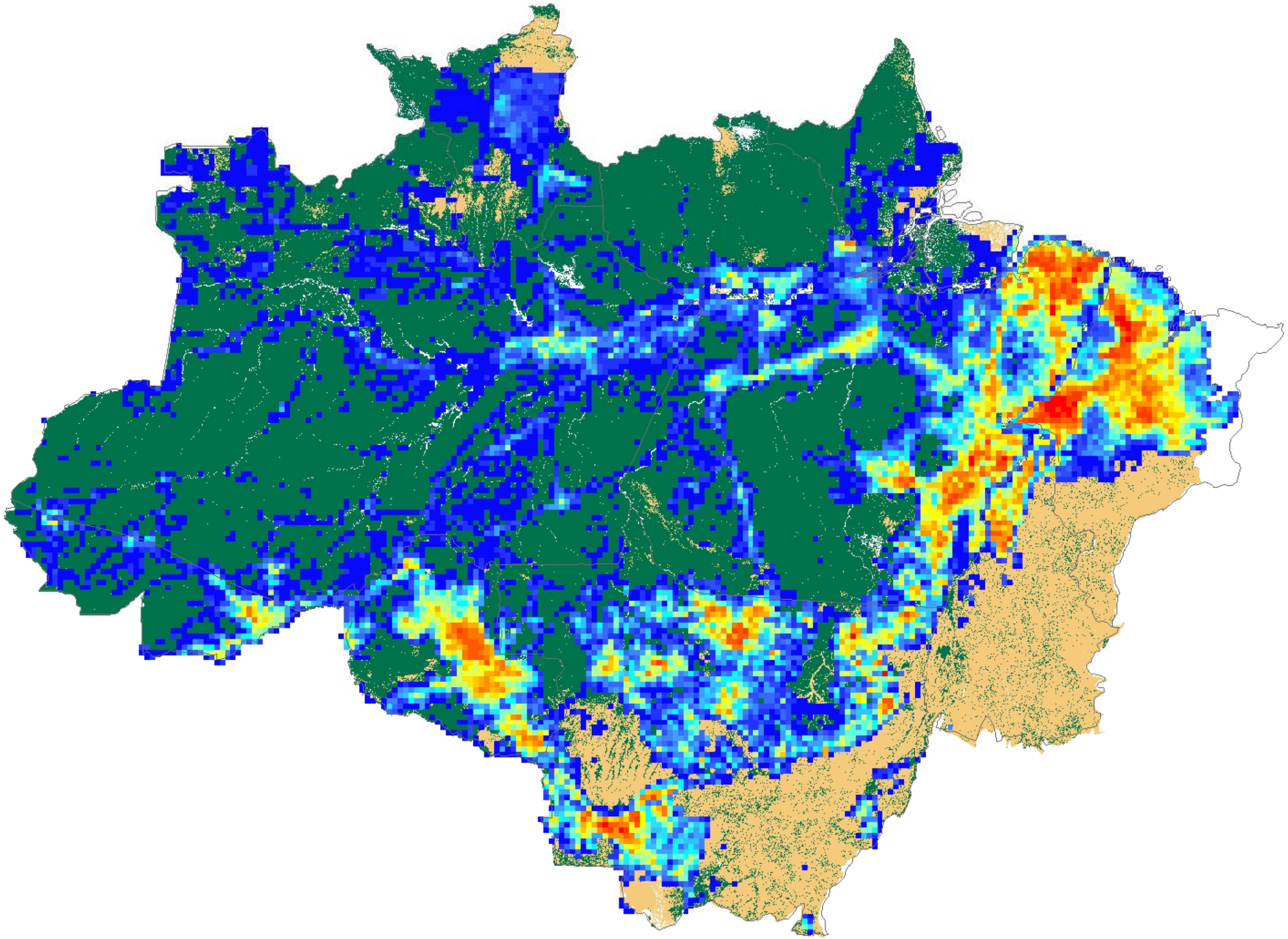
Logging storage areas (patios)

Tree fall gaps

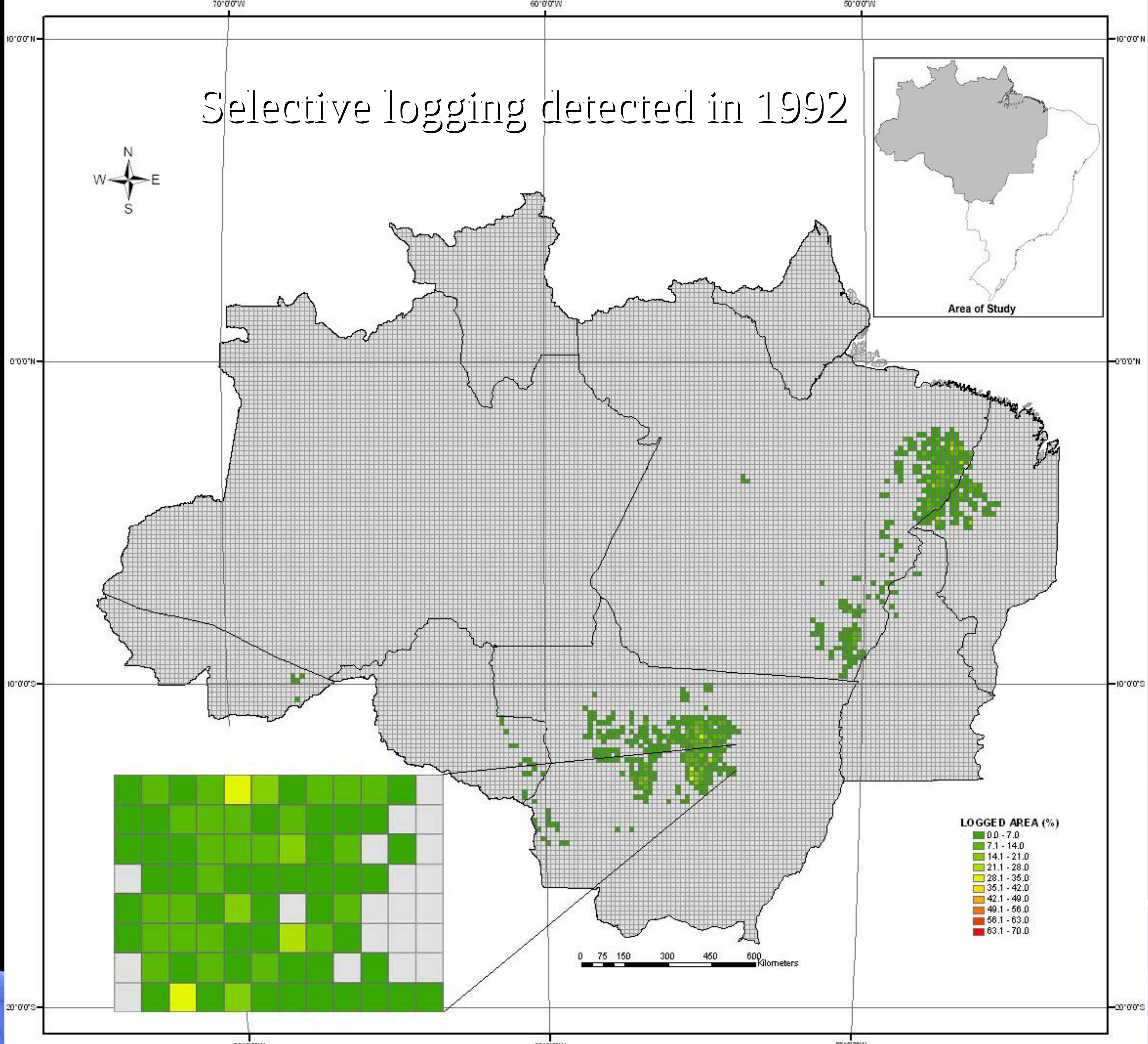
Stumps



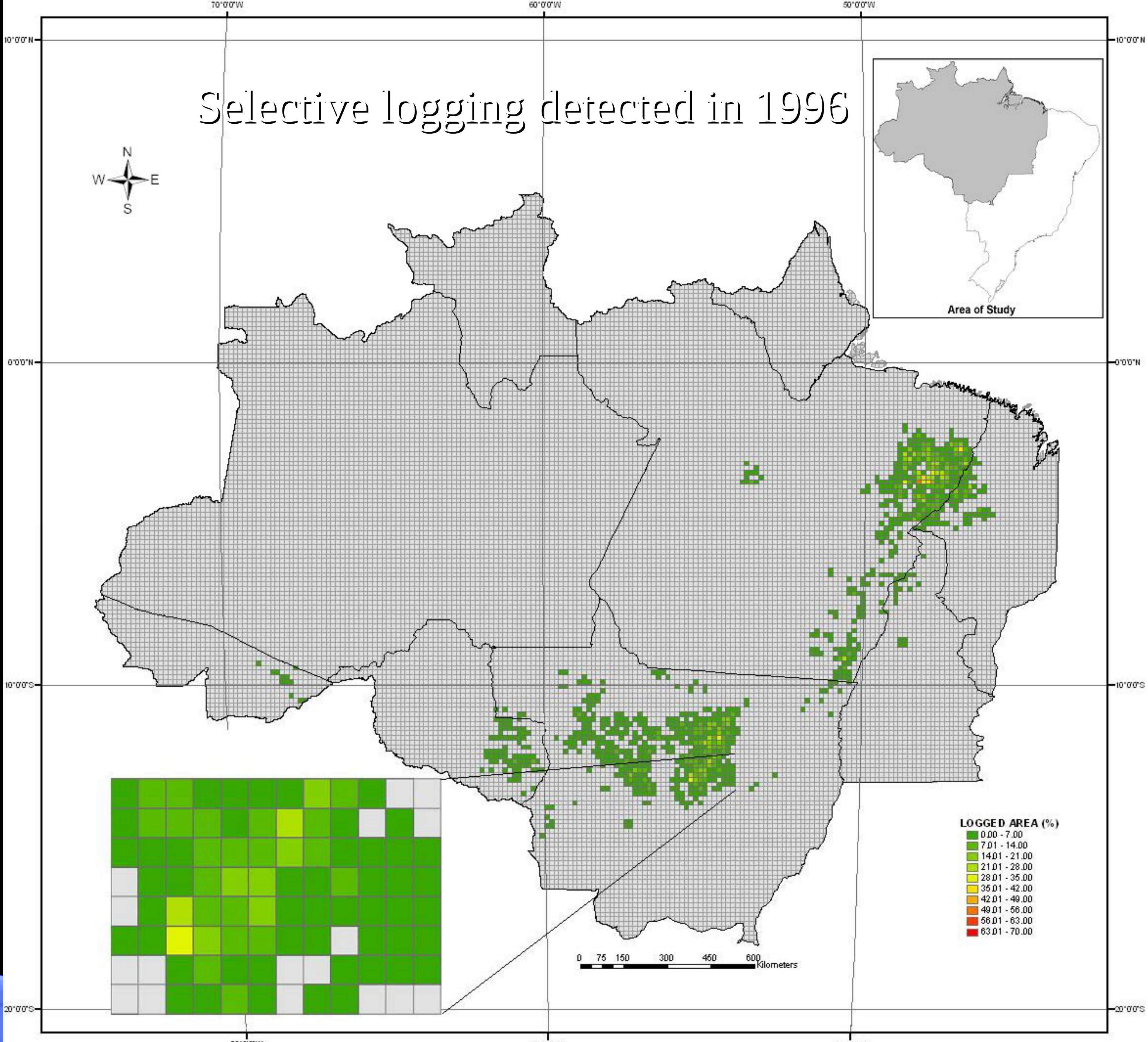




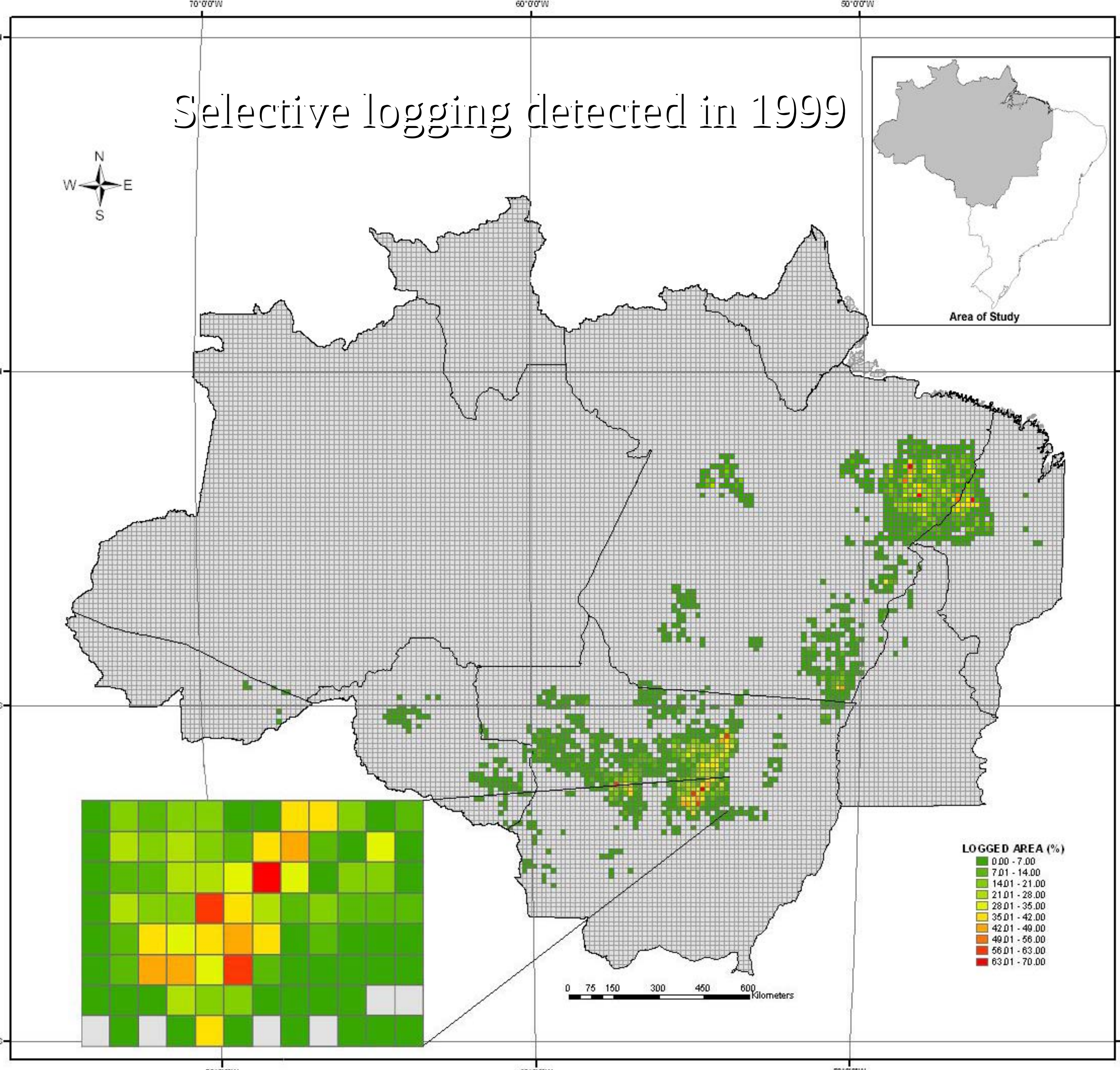
Selective logging detected in 1992



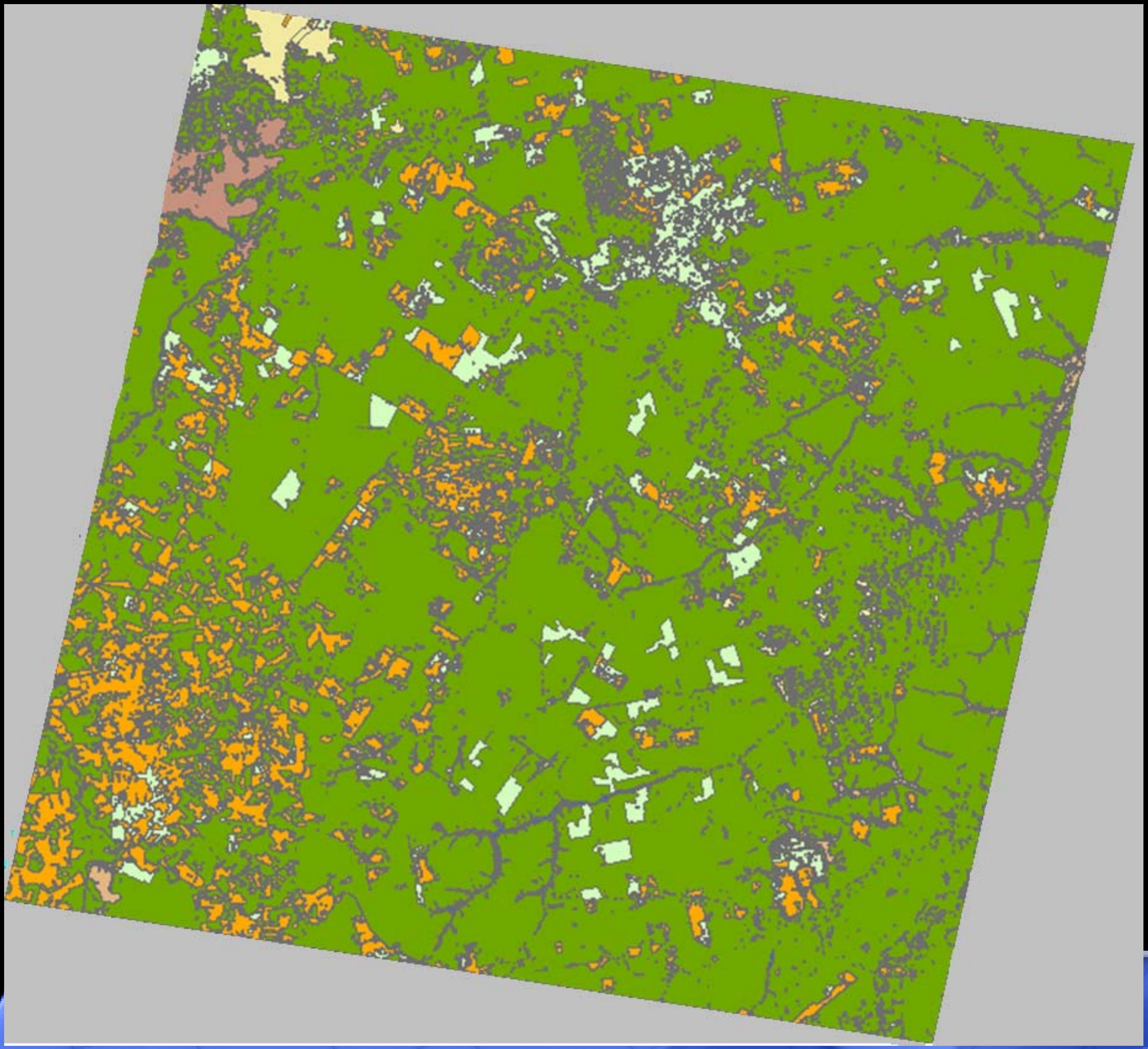
Selective logging detected in 1996



Selective logging detected in 1999

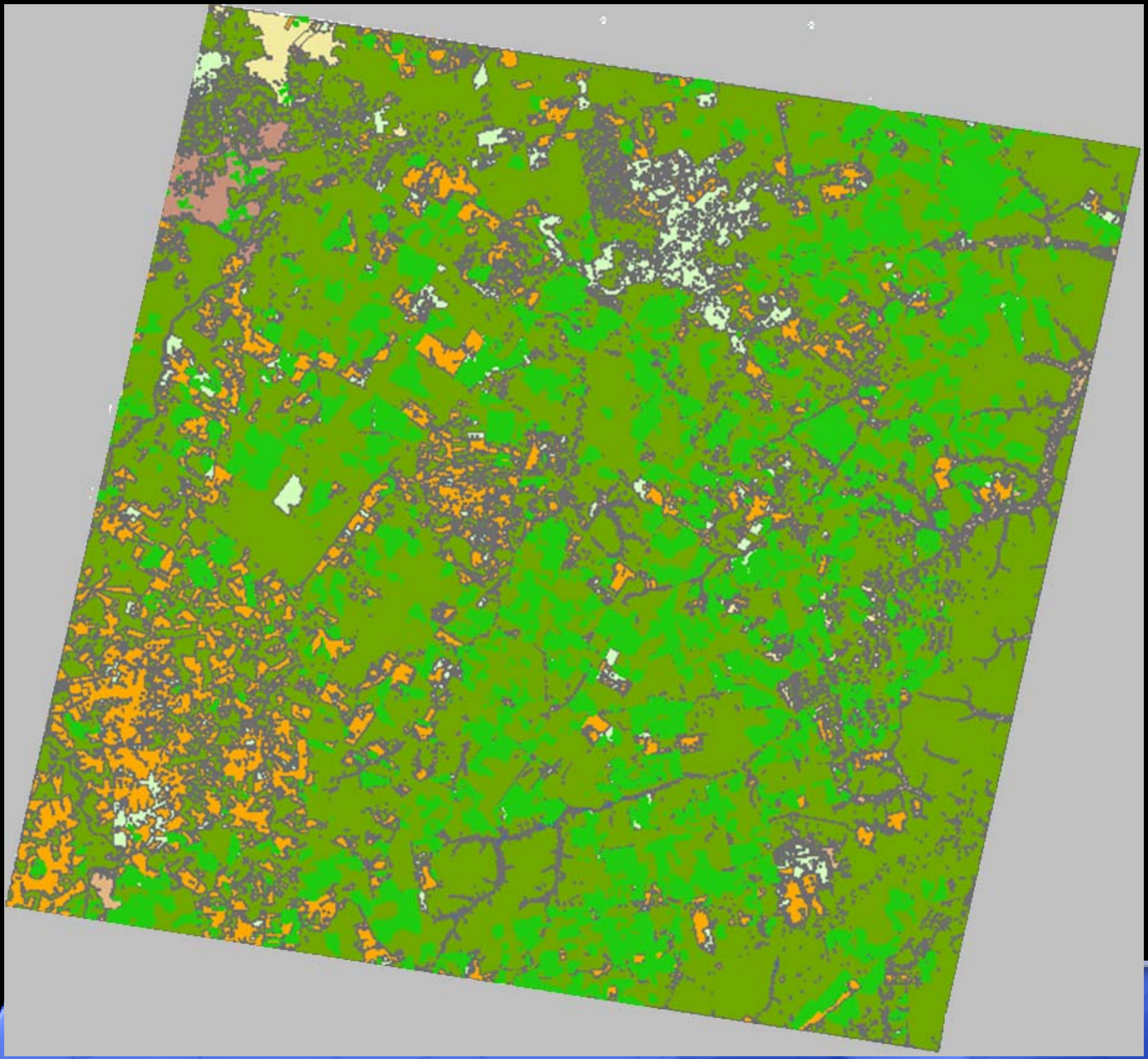


Forest, Deforestation, and Regeneration - 1996



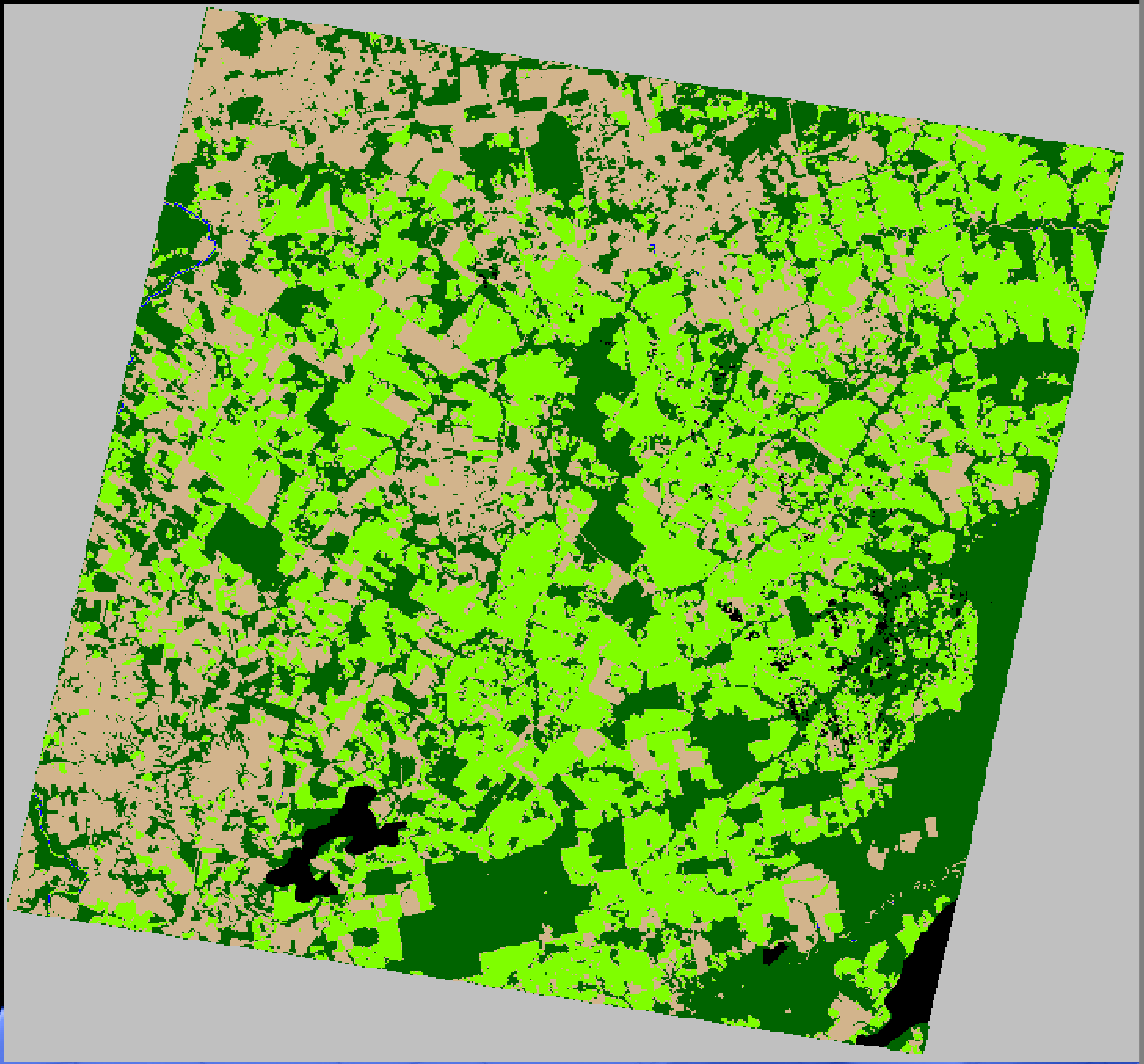
Mato Grosso, Brazil, path/row 226/068

Forest, Deforestation, Regeneration and Logging - 1996



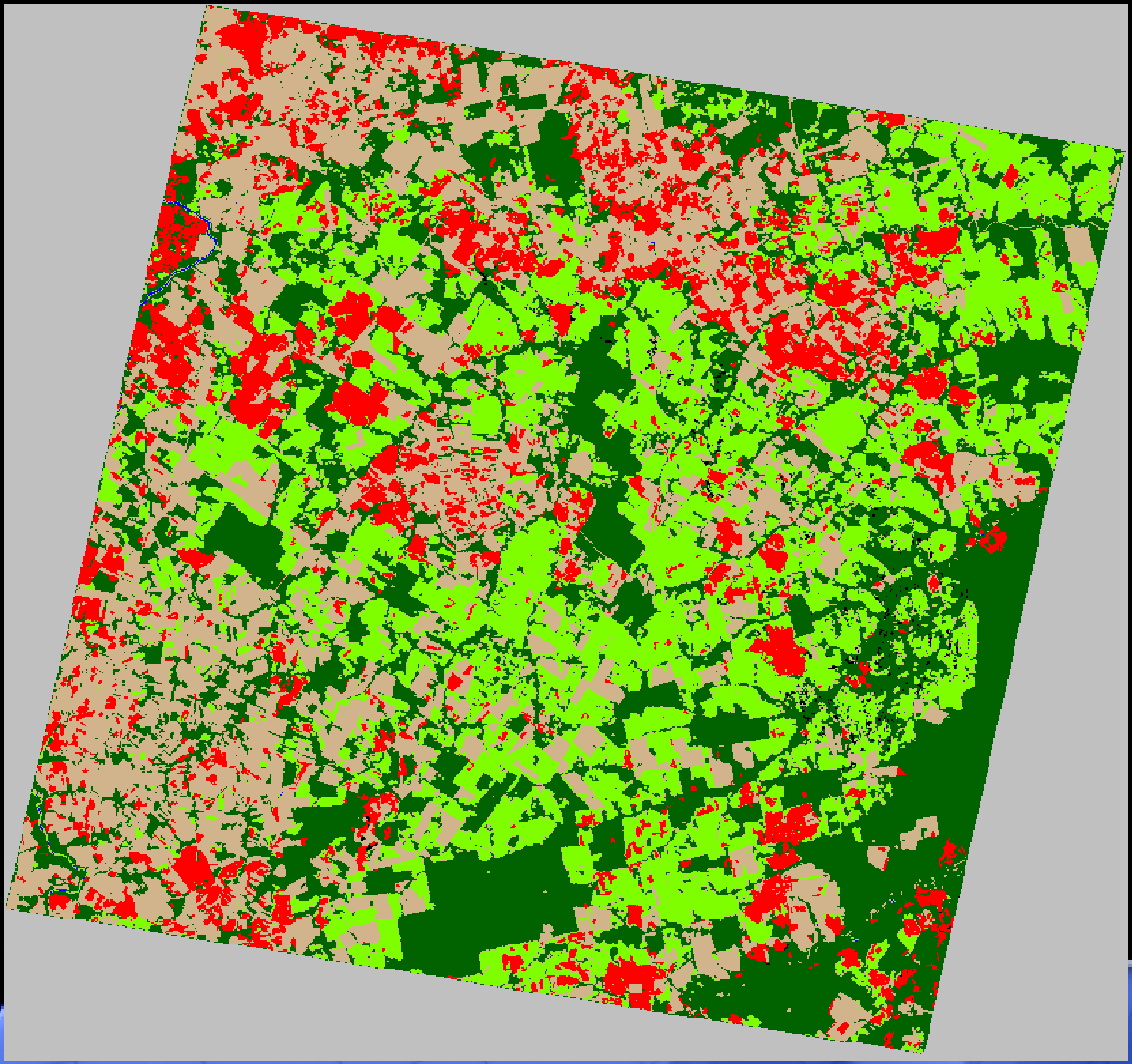
Mato Grosso, Brazil, path/row 226/068

Forest, Deforestation, and Logging - 2002



Mato Grosso, Brazil, path/row 226/068

Forest, Deforestation, Regeneration, Logging, and Fire - 2002



Mato Grosso, Brazil, path/row 226/068

Year	Forest 1000km	Defor 1000km	Regen 1000km	D+R/F %	Rate 1000km yr-1
1992	3,725	273	115	9.5	(15.0)
1996	3,571	243	175	11.7	16.2
1999	3,527	336	193	15.0	36.9

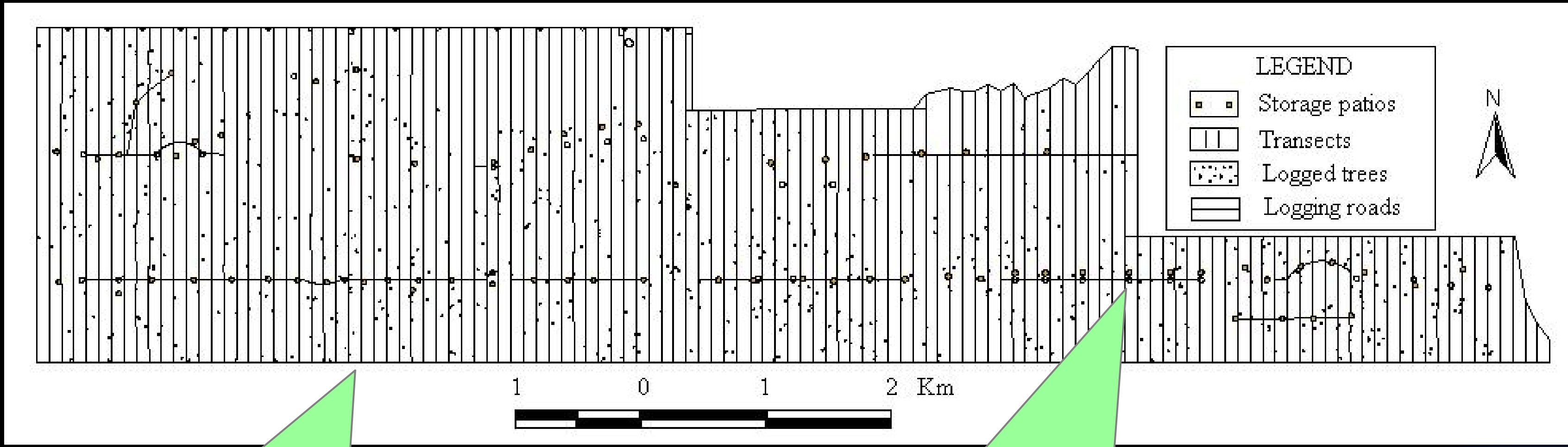
Total detected and increment of new logging areas Amazon-wide

Year	Amazon-wide logging area (Km2)		
	Total detected	Increment of new logging	
		Based on equations (*)	Based on annual average (*)
1992	5,979.80	3,689	2,547
1996	10,064.10	5,107	4,361
1999	26,085.40	11,638	11,889

* Note: Extrapolated from the Mato Grosso and Rondonia case studies

Methodology validation:

Rondonia case study



Forest inventory

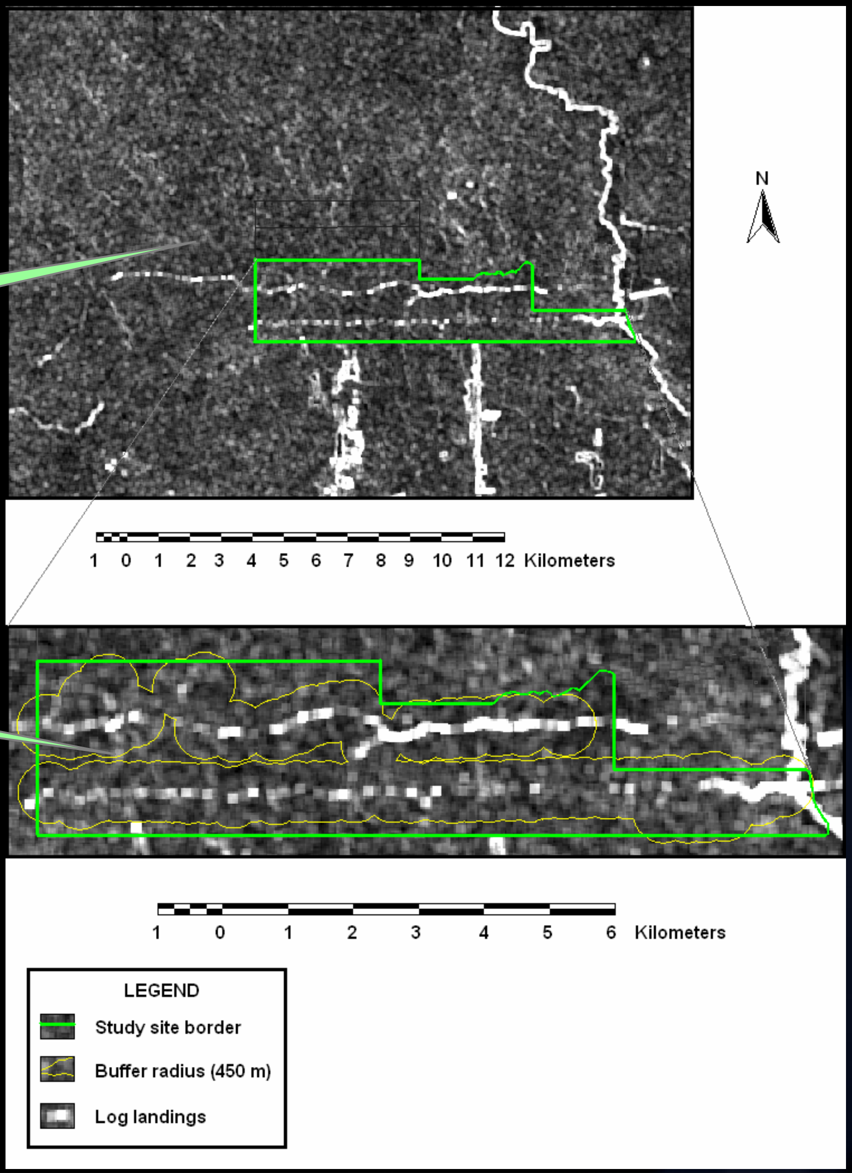
Patio, road, and tree locations

Validation:

Rondonia case study

Textural image (Landsat ETM+, Band 5)

Buffer radius (450m) around log landings



Validation: Rondonia case study