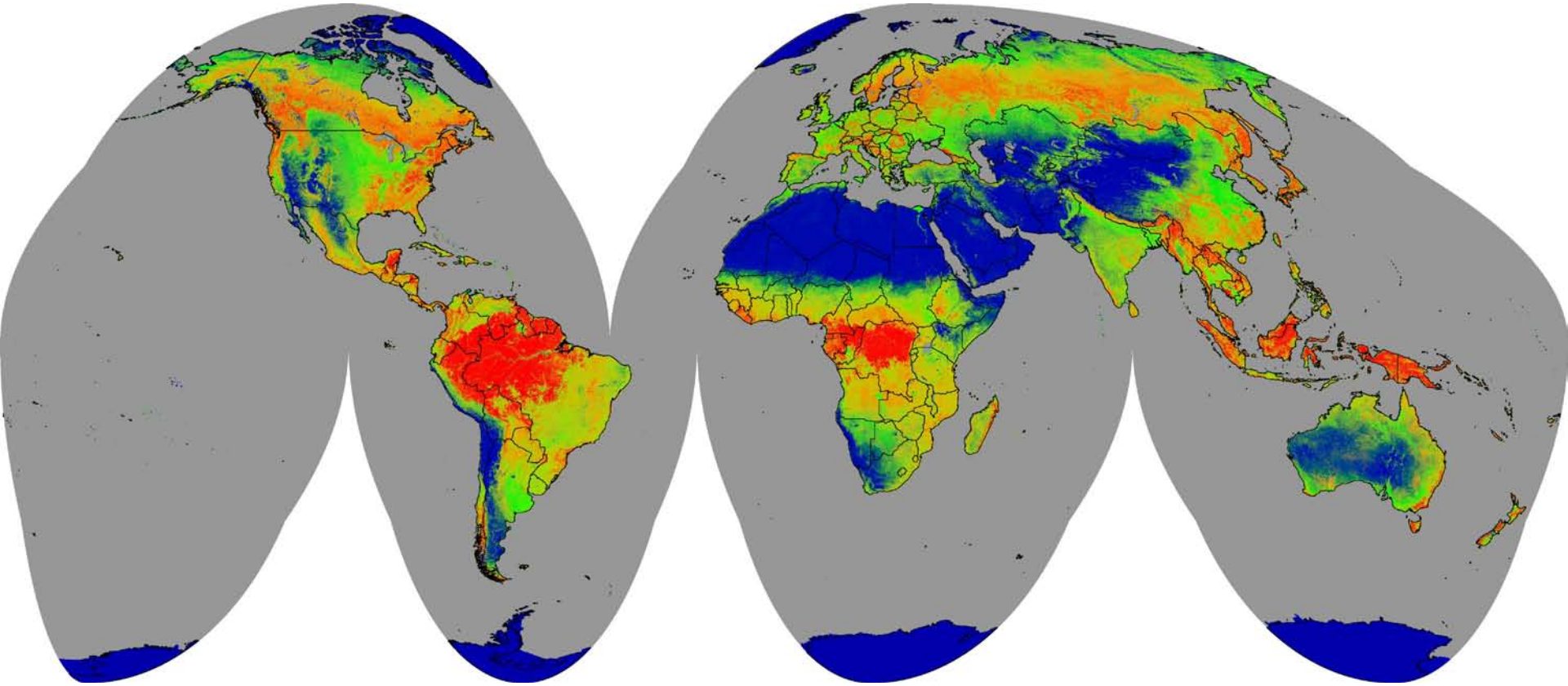
Using MODIS and Landsat for monitoring forest cover and change

M. Hansen[1], C. Justice[2], P. Potapov[1], S. Stehman[3],
M. Broich[1], E. Lindquist[1], B. Arunarwati[1]

[1]South Dakota State University
[2]University of Maryland
[3]State University of New York

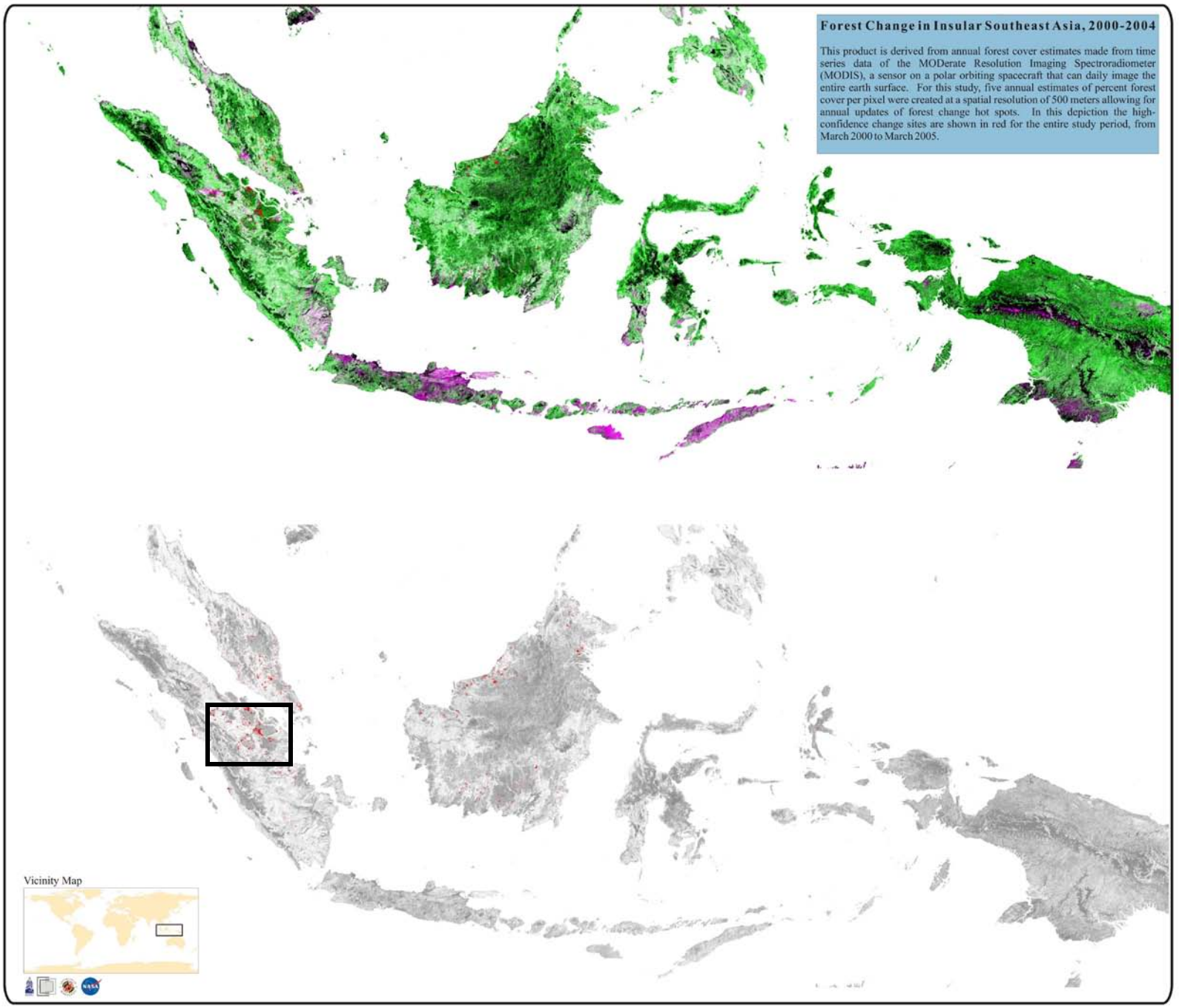
SDSU

MODIS Vegetation Continuous Fields – 2000



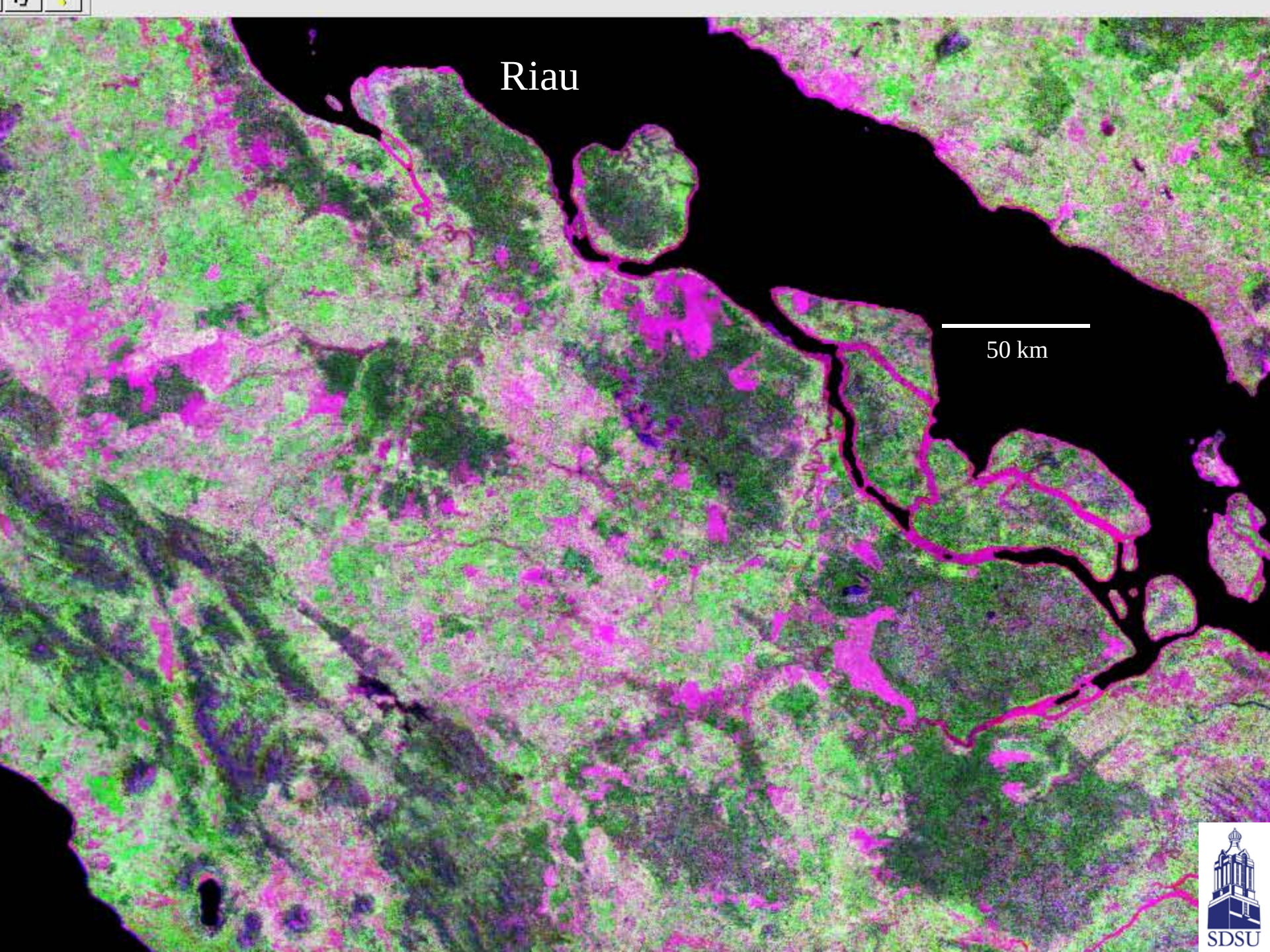
Percent cover 0% Bare ground Grass/shrubs/moss Trees 100%

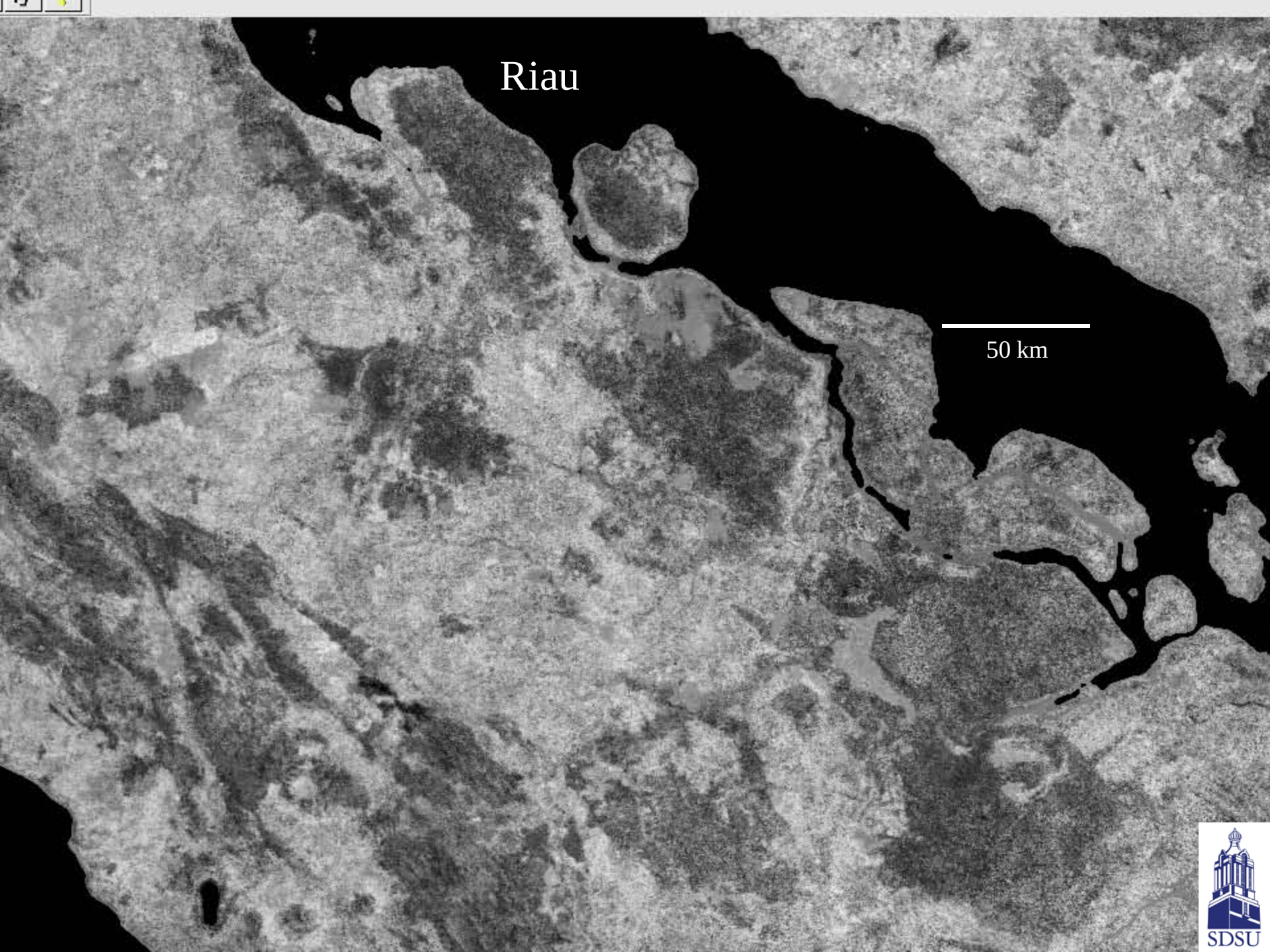
SDSU

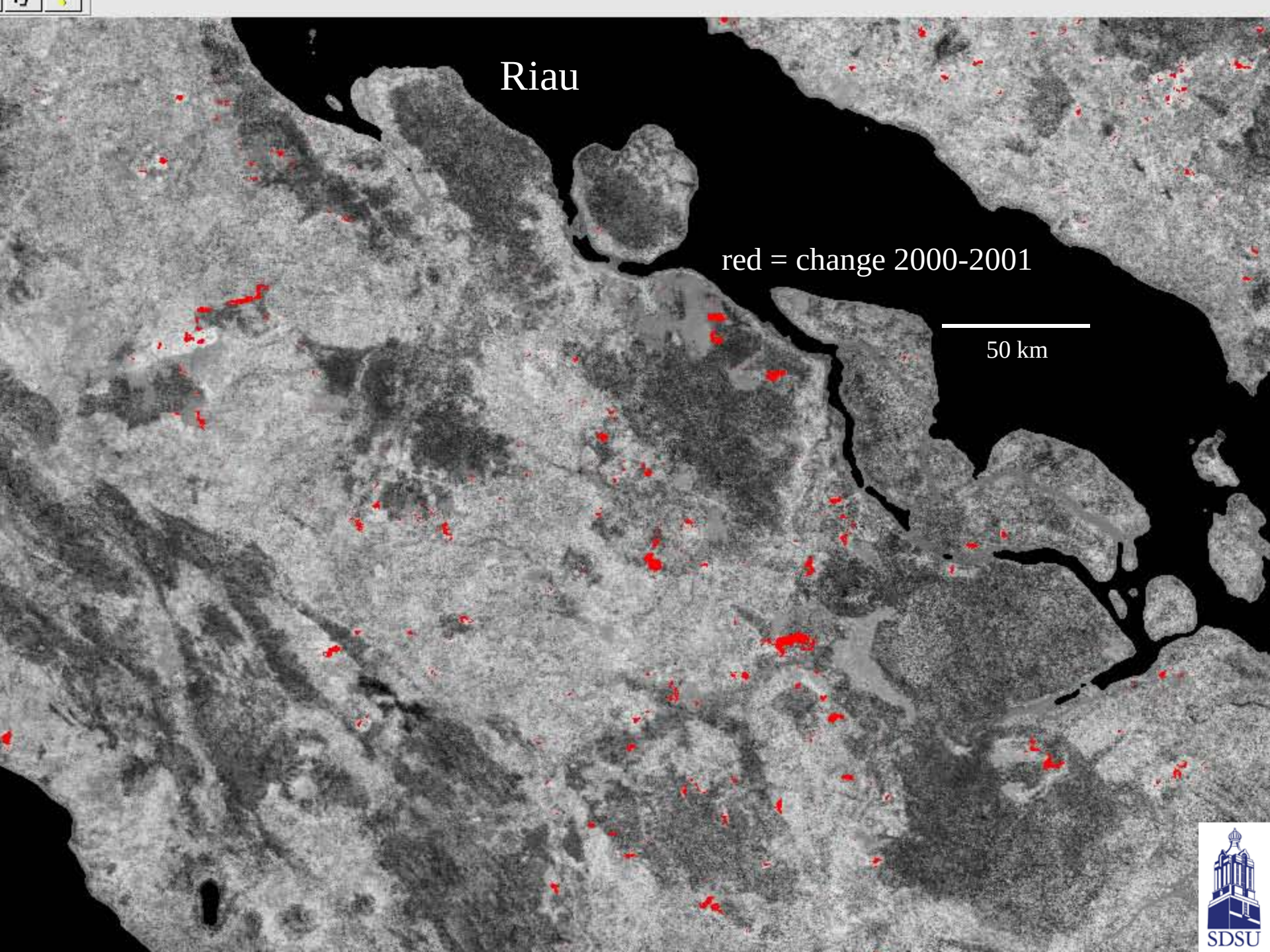


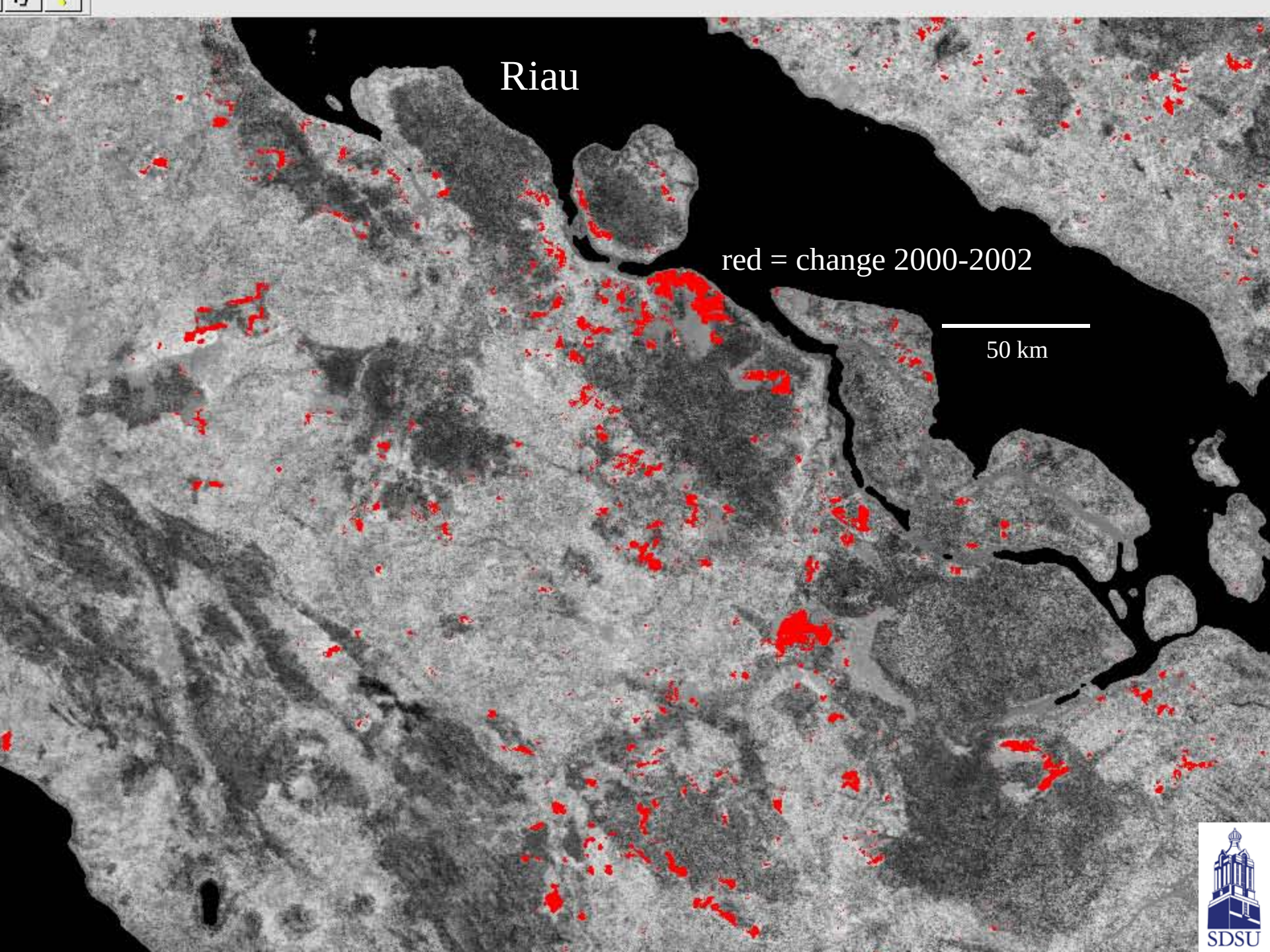
Forest Change in Insular Southeast Asia

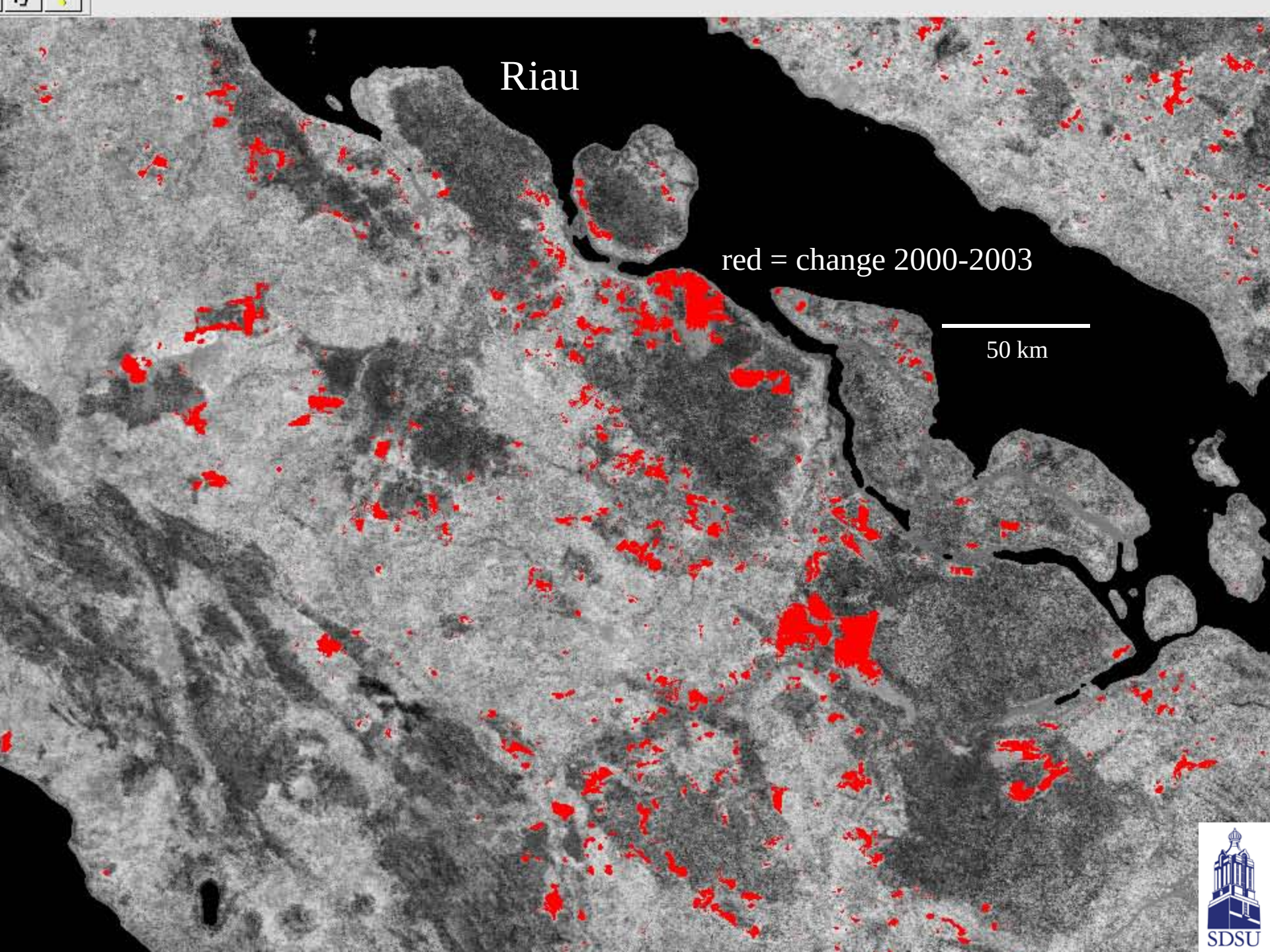
SDSU

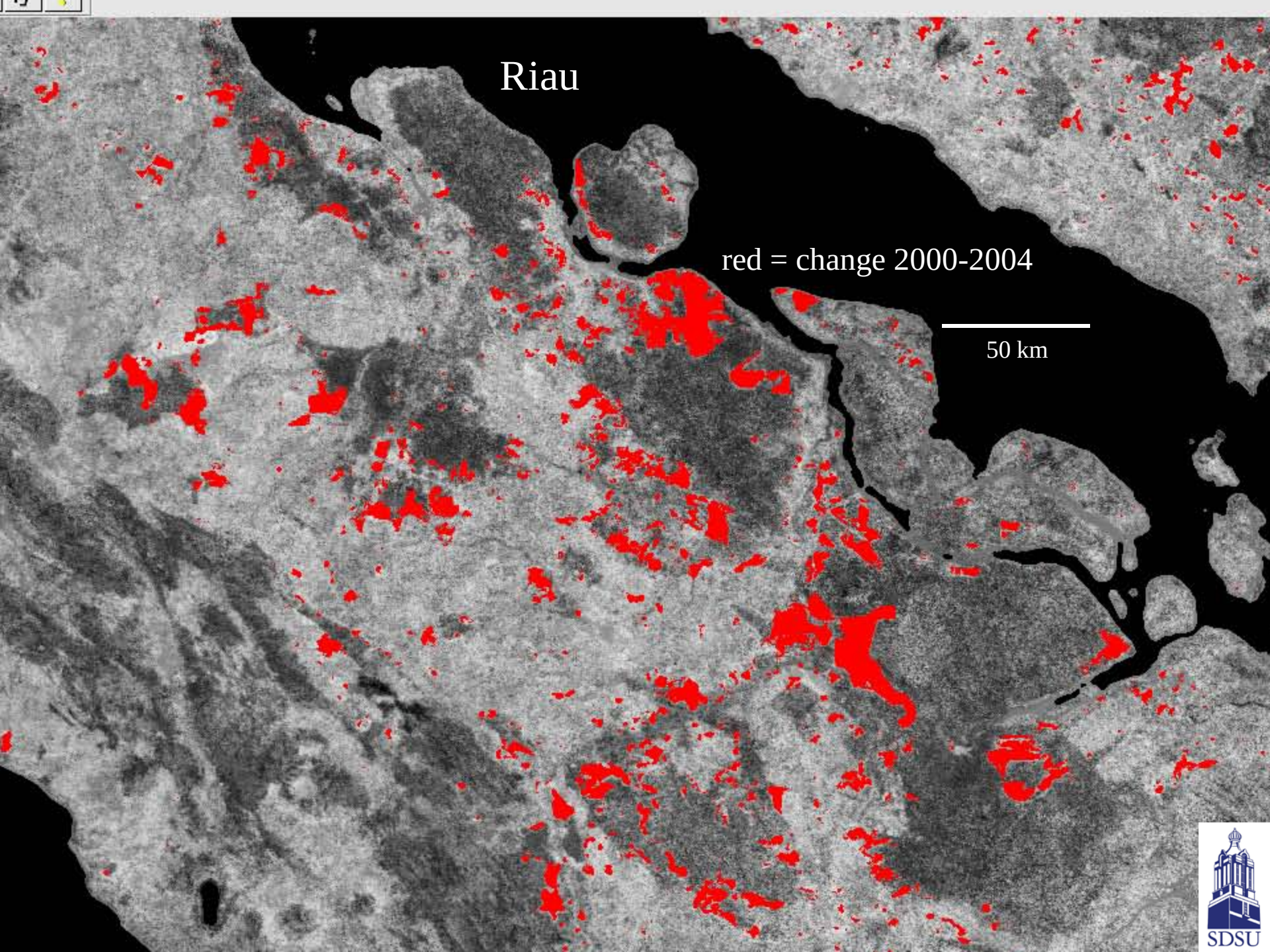

Riau
50 km

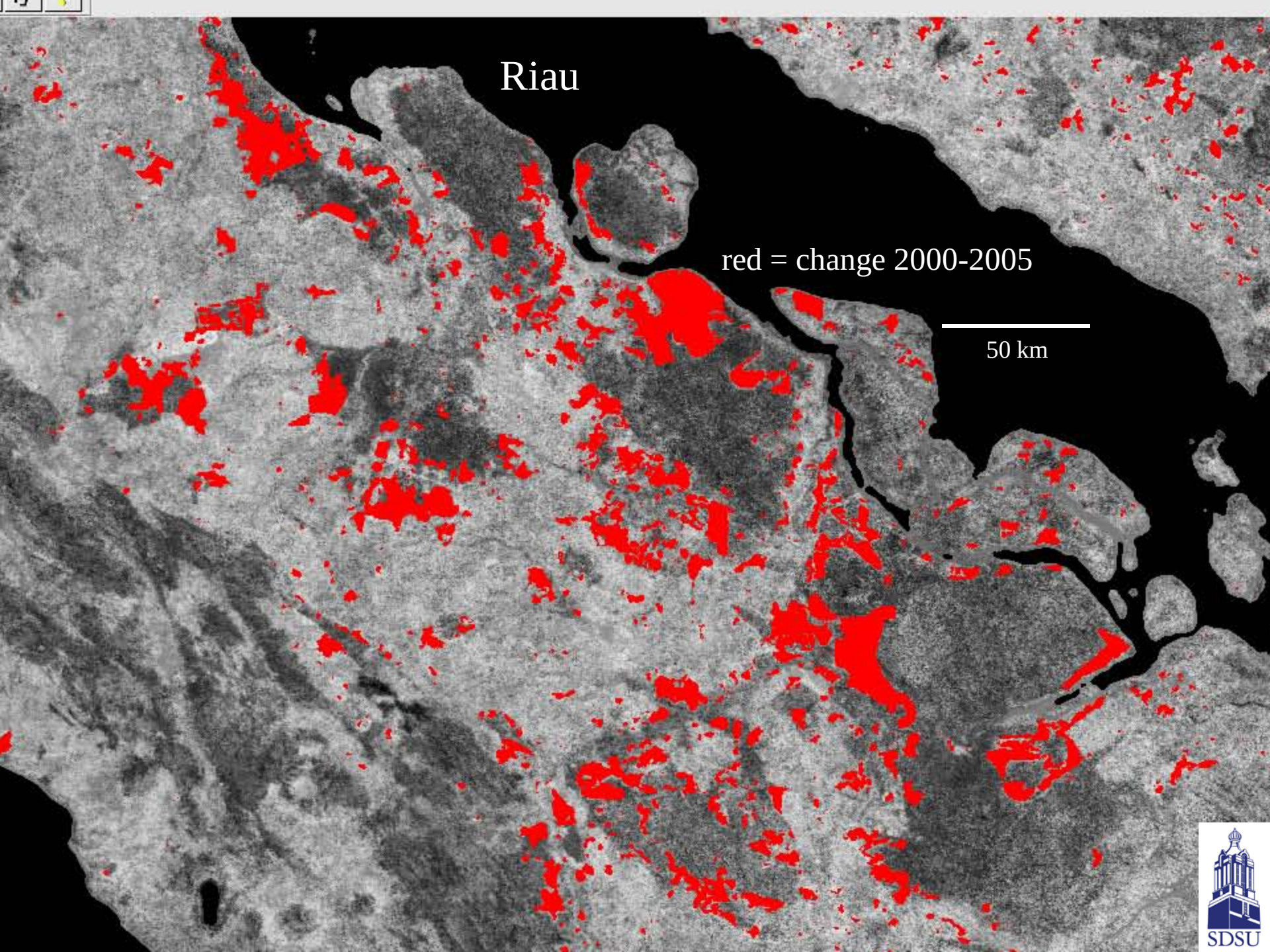

Riau
50 km

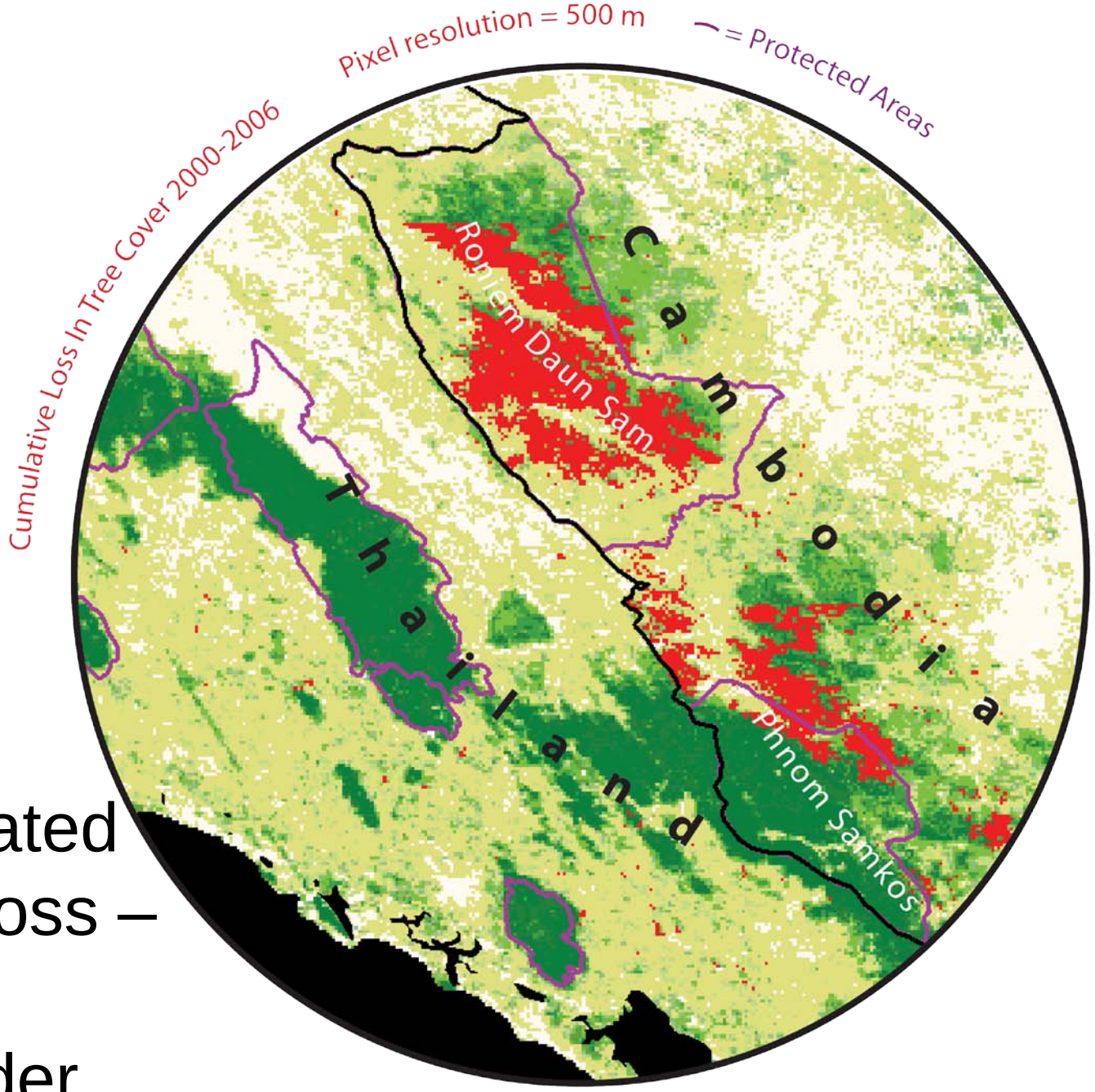

Riau
red = change 2000-2001
50 km


Riau
red = change 2000-2002
50 km
SDSU


Riau
red = change 2000-2003
50 km
SDSU


Riau
red = change 2000-2004
50 km
SDSU

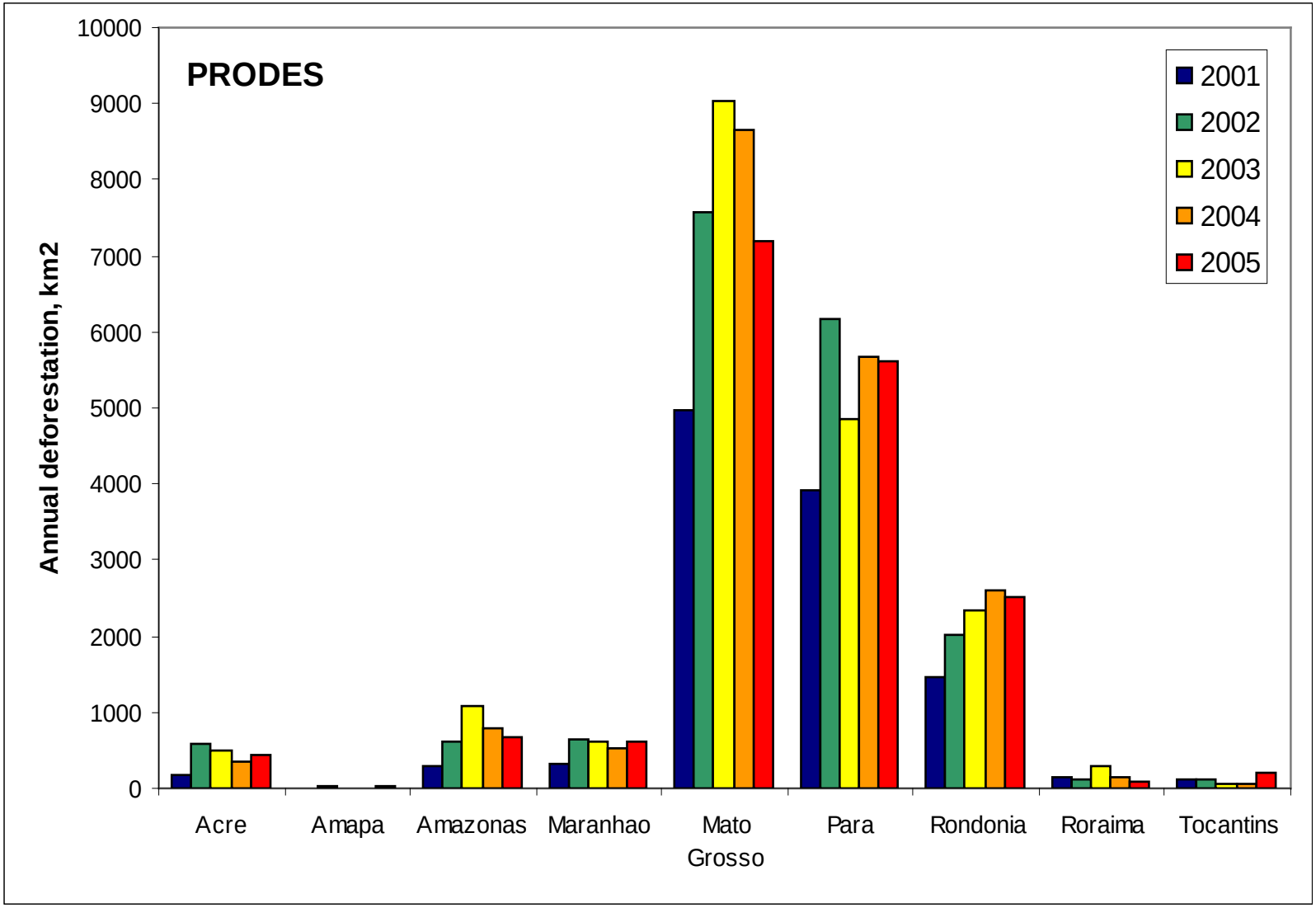

Riau
red = change 2000-2005
50 km
SDSU



MODIS indicated forest cover loss – Cambodia / Thailand border

MODIS change analysis verification using independent datasets

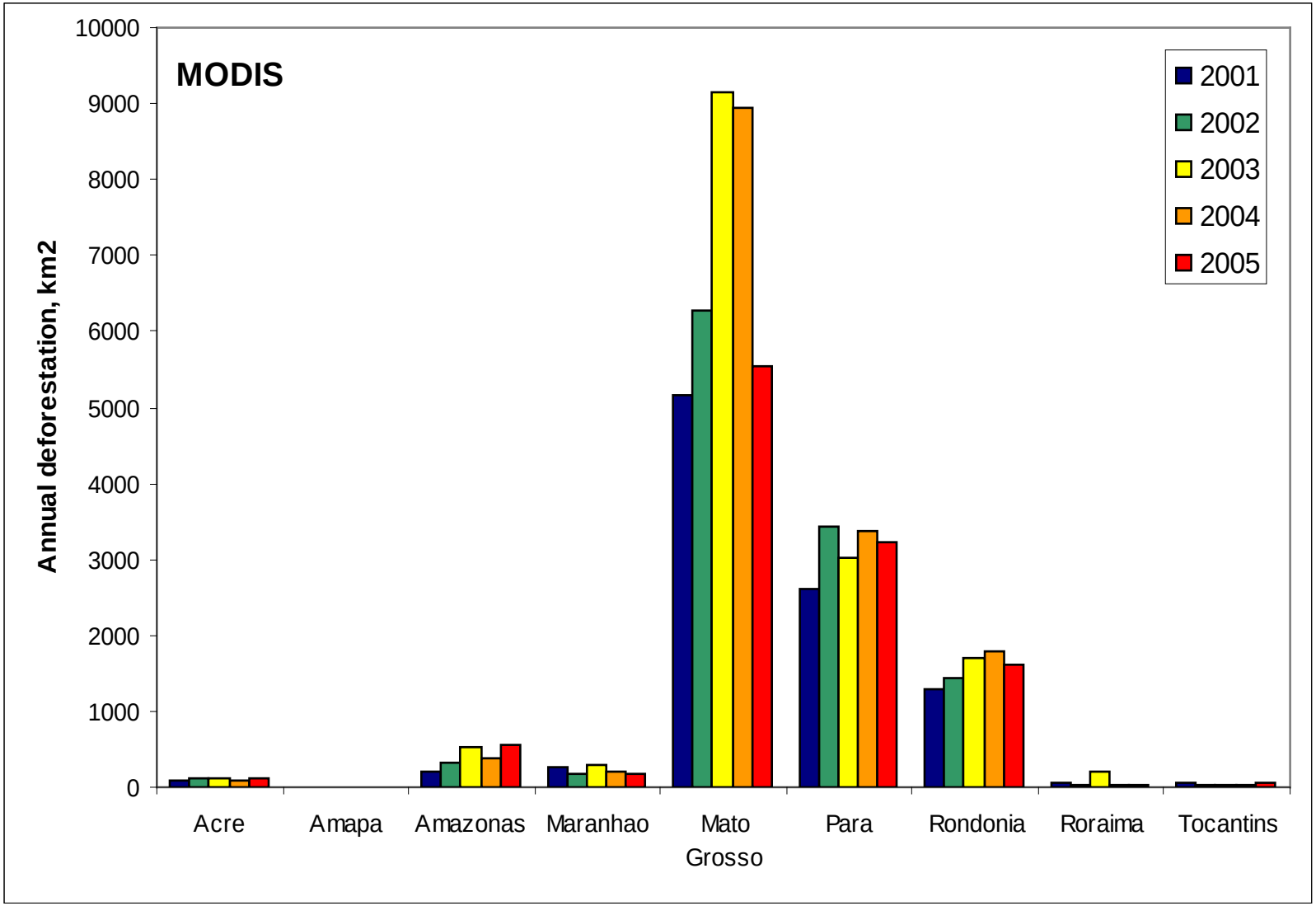
PRODES data for Brazilian Amazon



SDSU

MODIS change analysis verification using independent datasets

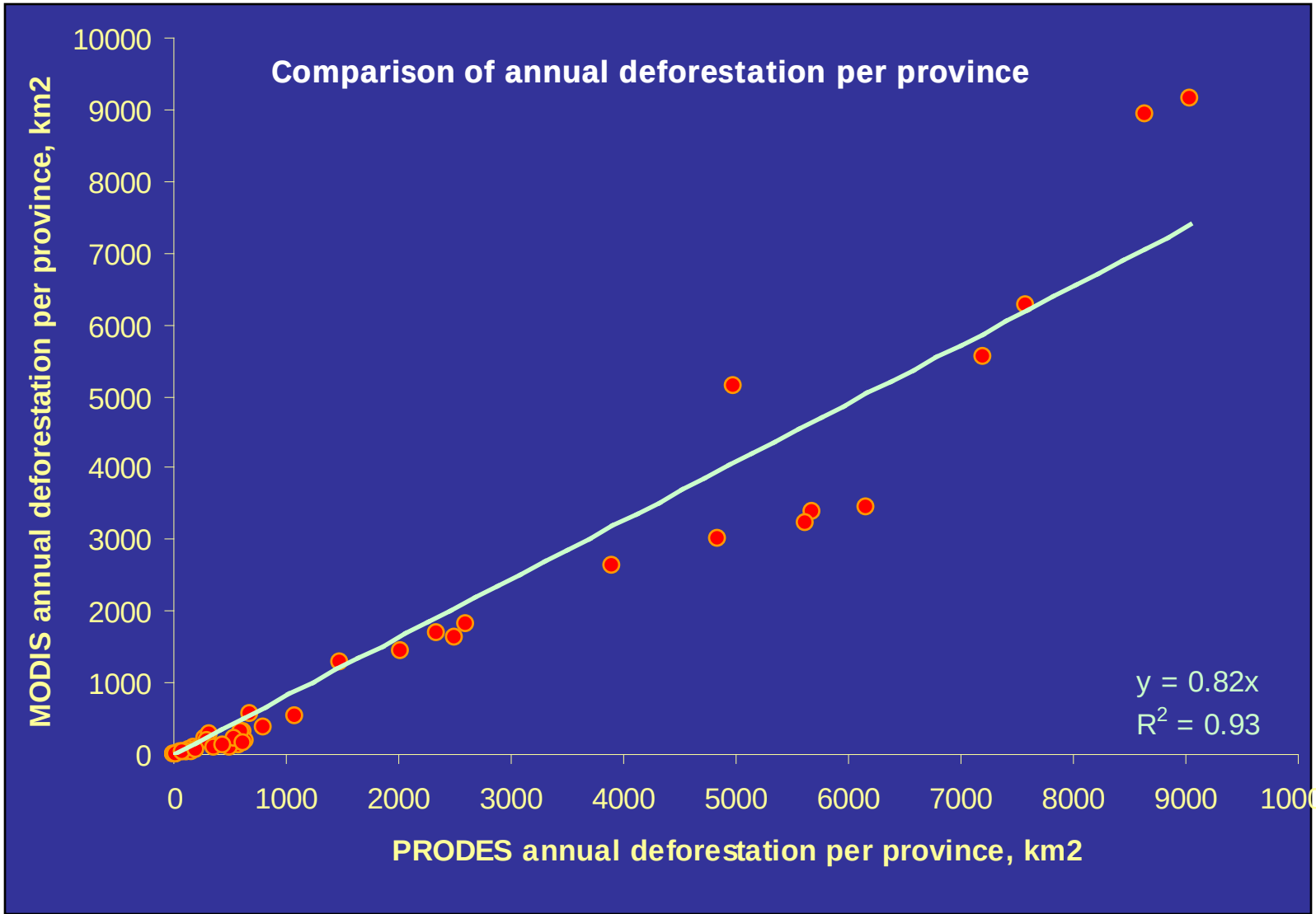
MODIS data for Brazilian Amazon



SDSU

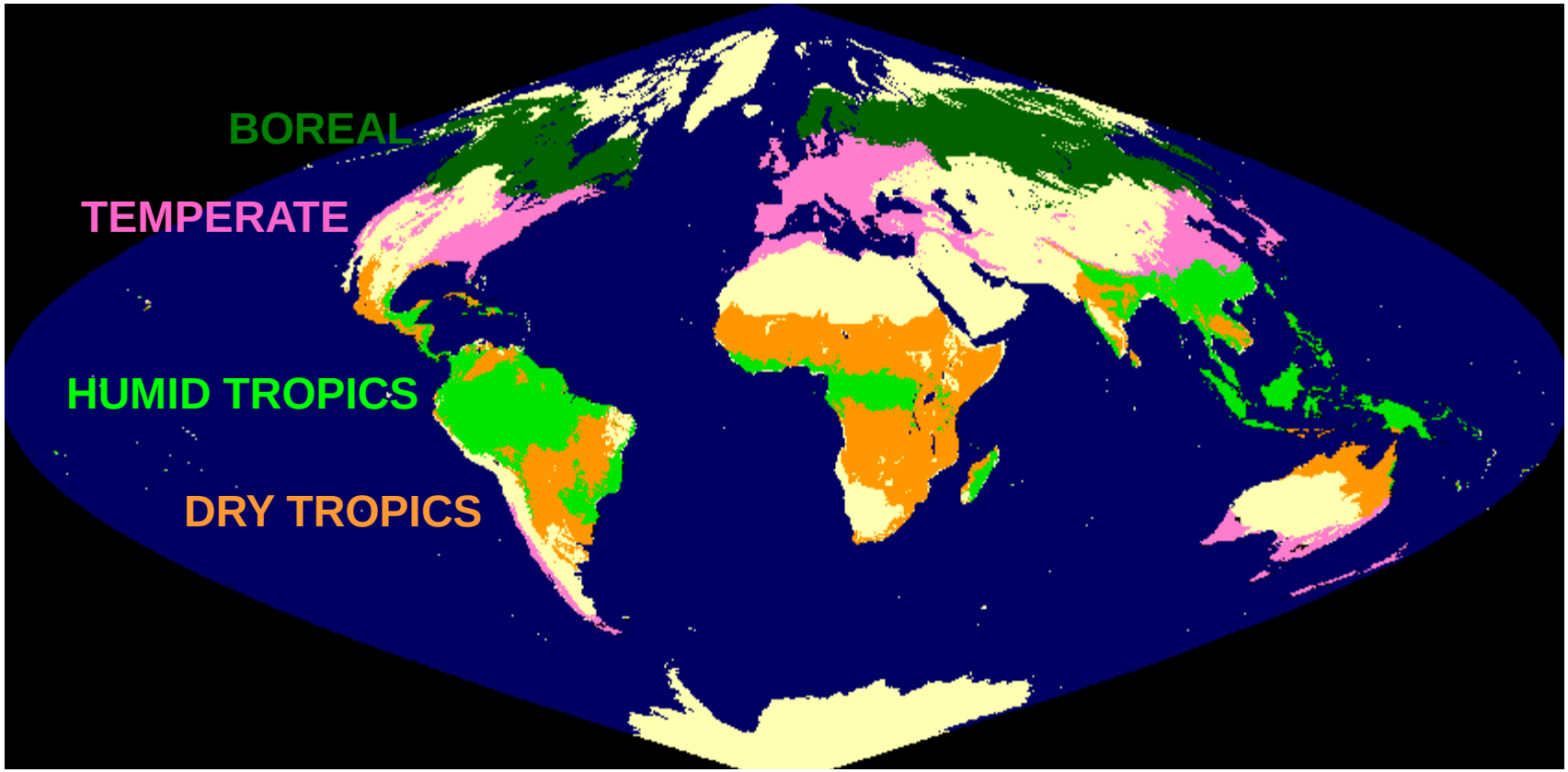
MODIS change analysis verification using independent datasets

PRODES data for Brazilian Amazon



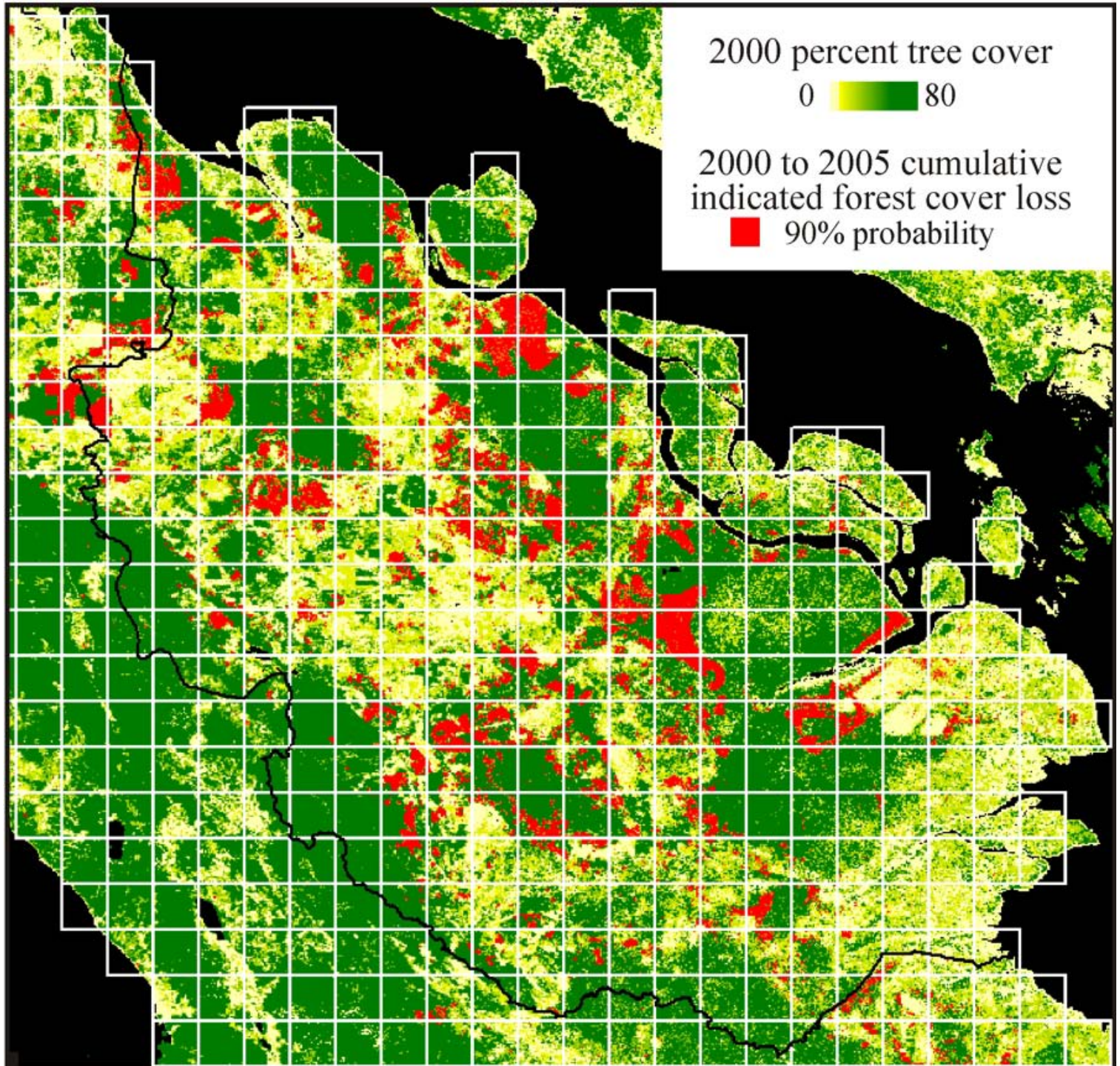
SDSU

Global forested biomes



WWF ecoregions

SDSU


2000 percent tree cover
0
80
2000 to 2005 cumulative
indicated forest cover loss
90% probability

SDSU

From per pixel hotspot map to change probability strata

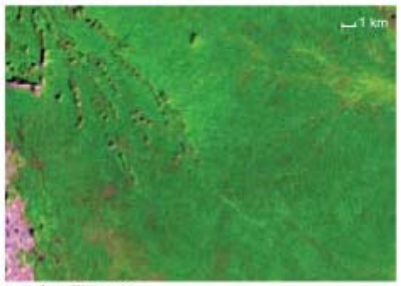
Low change Medium change High change

SDSU

Stratified samples

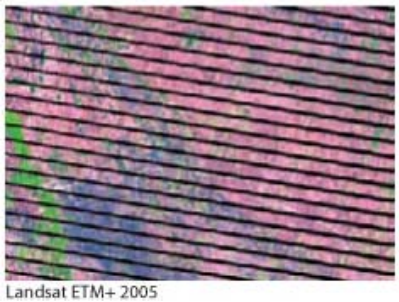
Low change Medium change High change

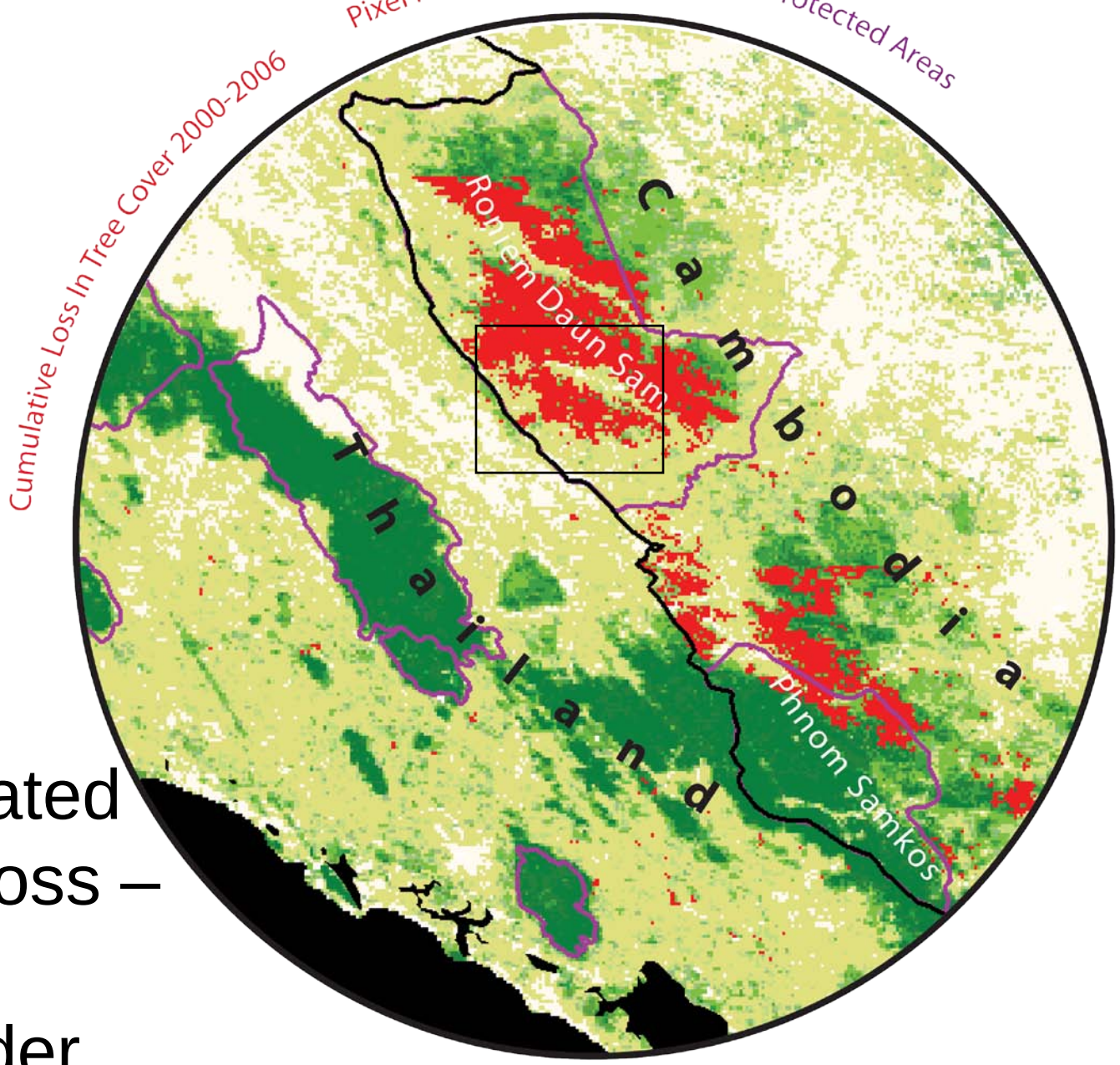
SDSU



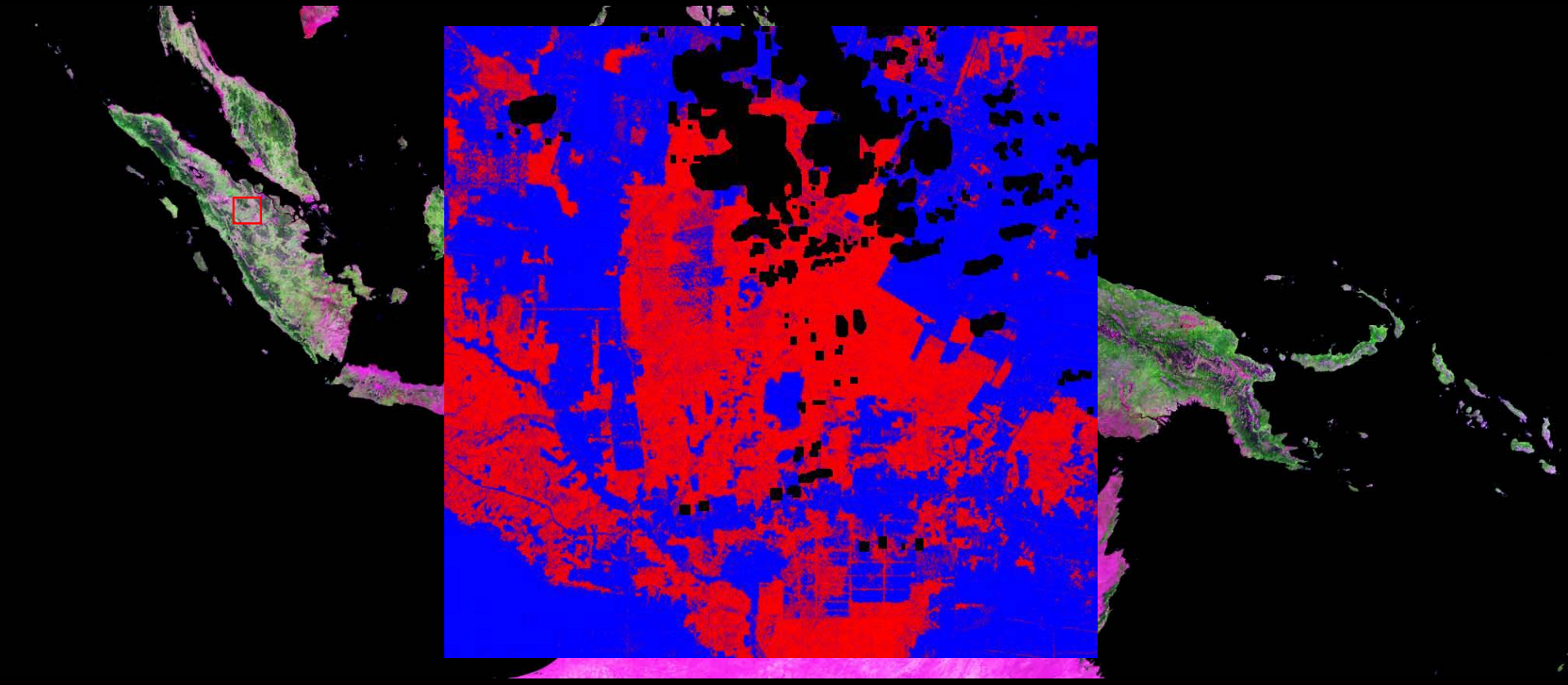
Landsat TM 1990


Landsat ETM+ 2001

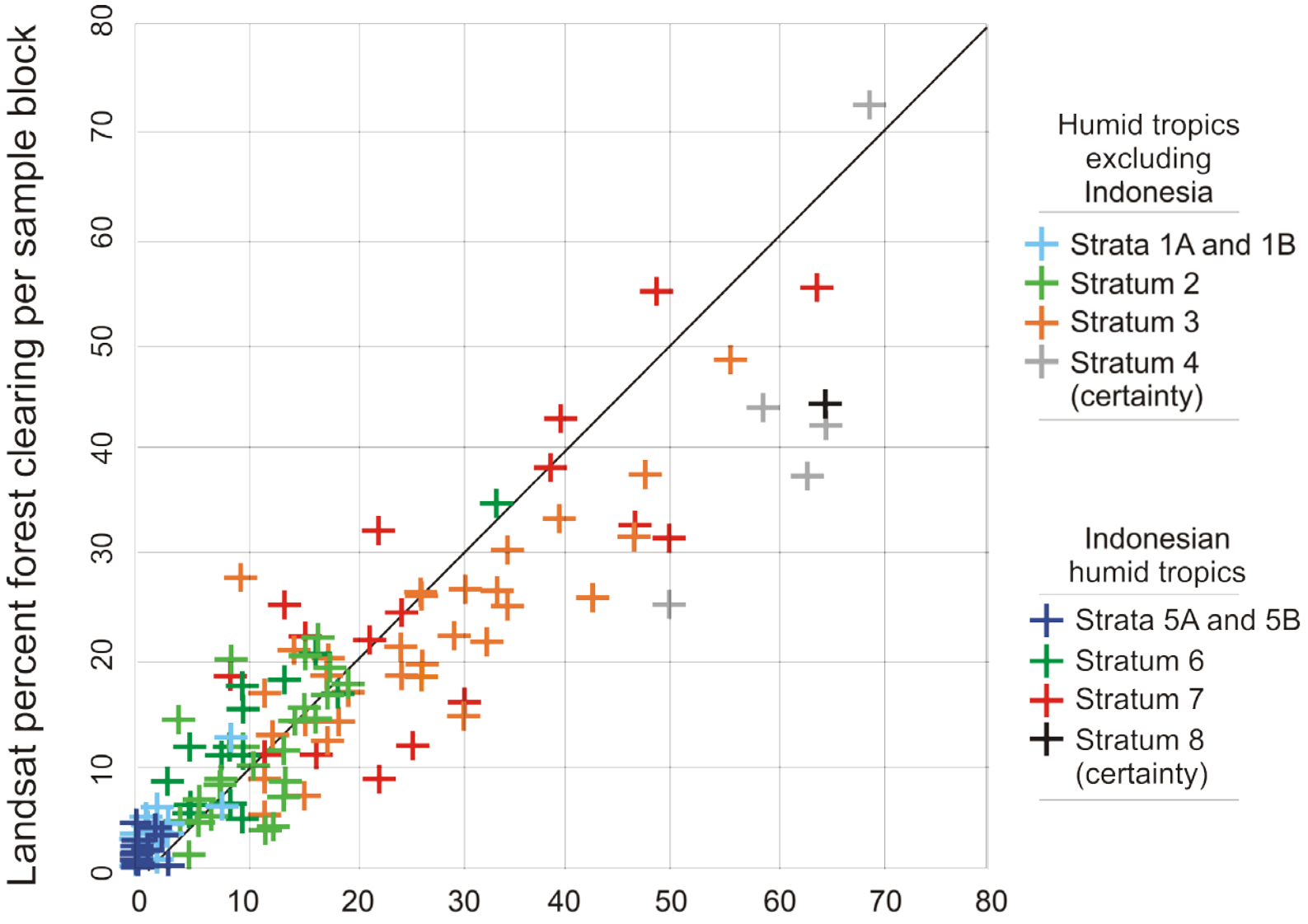

Landsat ETM+ 2005



MODIS indicated forest cover loss – Cambodia / Thailand border



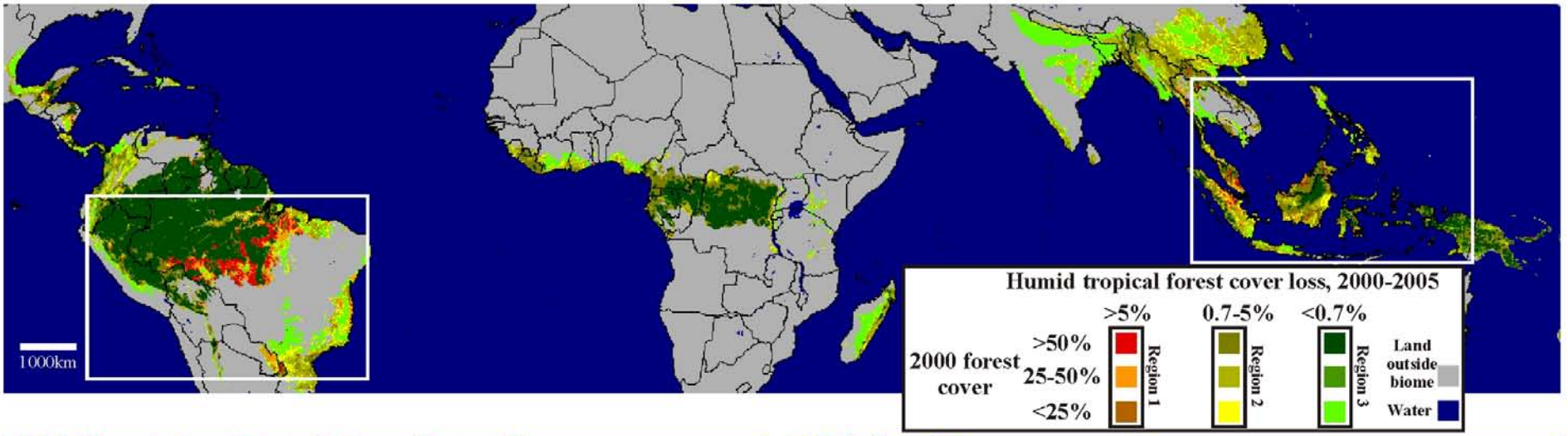
SDSU

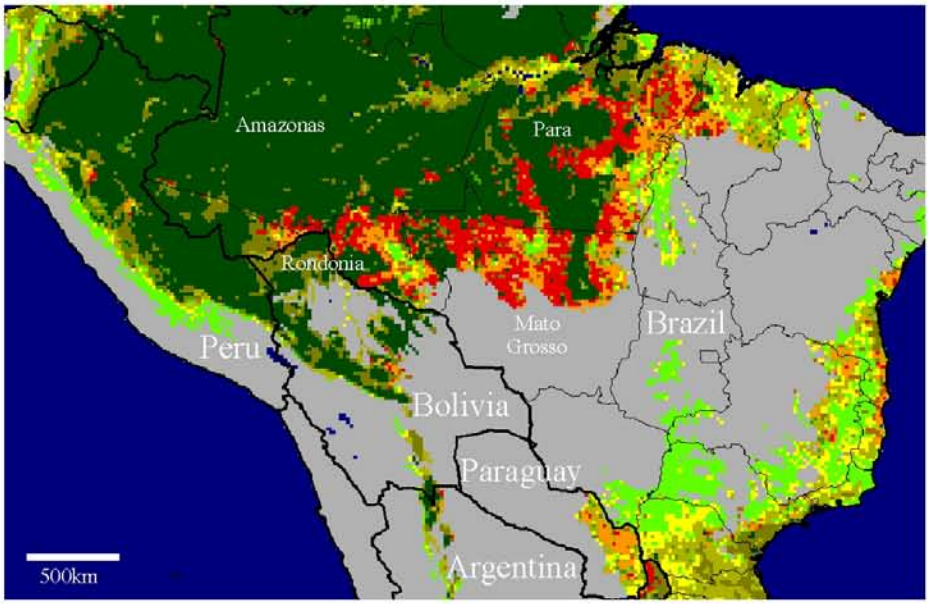

Landsat percent forest clearing per sample block
0
10
20
30
40
50
60
70
80
MODIS percent forest clearing per sample block
(75% change probability threshold)
Humid tropics excluding Indonesia
Strata 1A and 1B
Stratum 2
Stratum 3
Stratum 4 (certainty)
Indonesian humid tropics
Strata 5A and 5B
Stratum 6
Stratum 7
Stratum 8 (certainty)

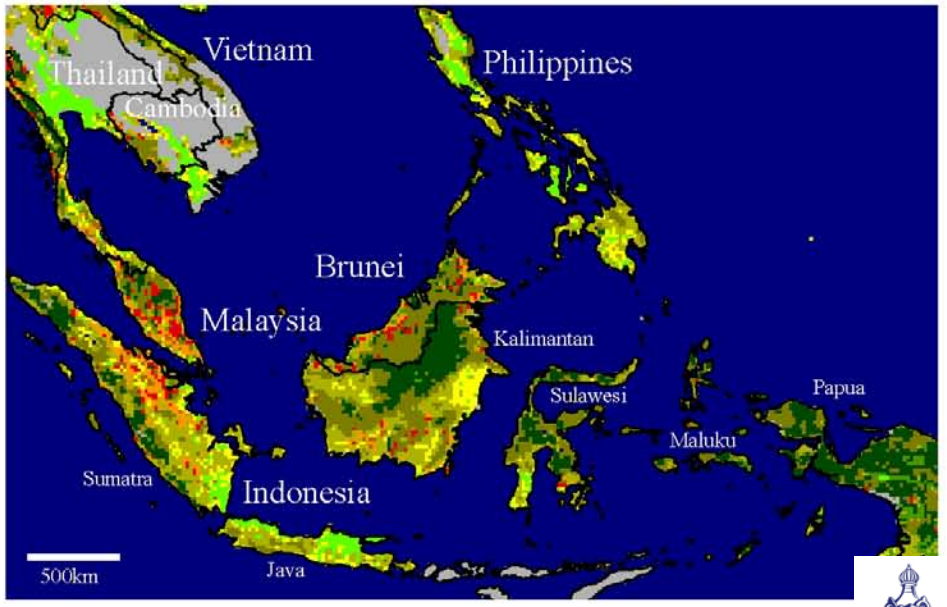
SDSU

Results

Landsat-calibrated change estimates for Humid Tropics biome

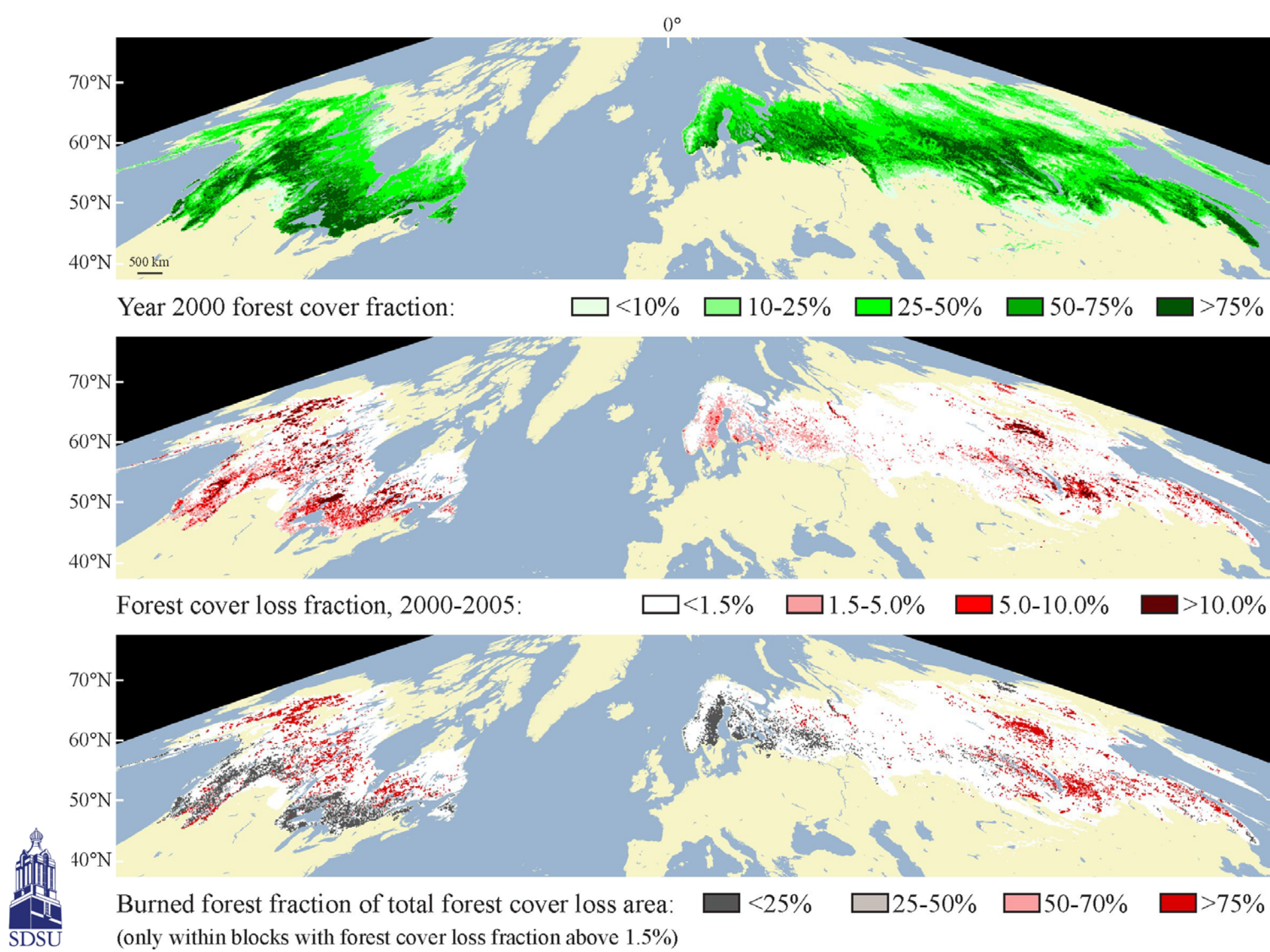






27.2 Mha lost equaling 2.36% of year 2000 forest cover, 47.8% of total in Brazil

SDSU

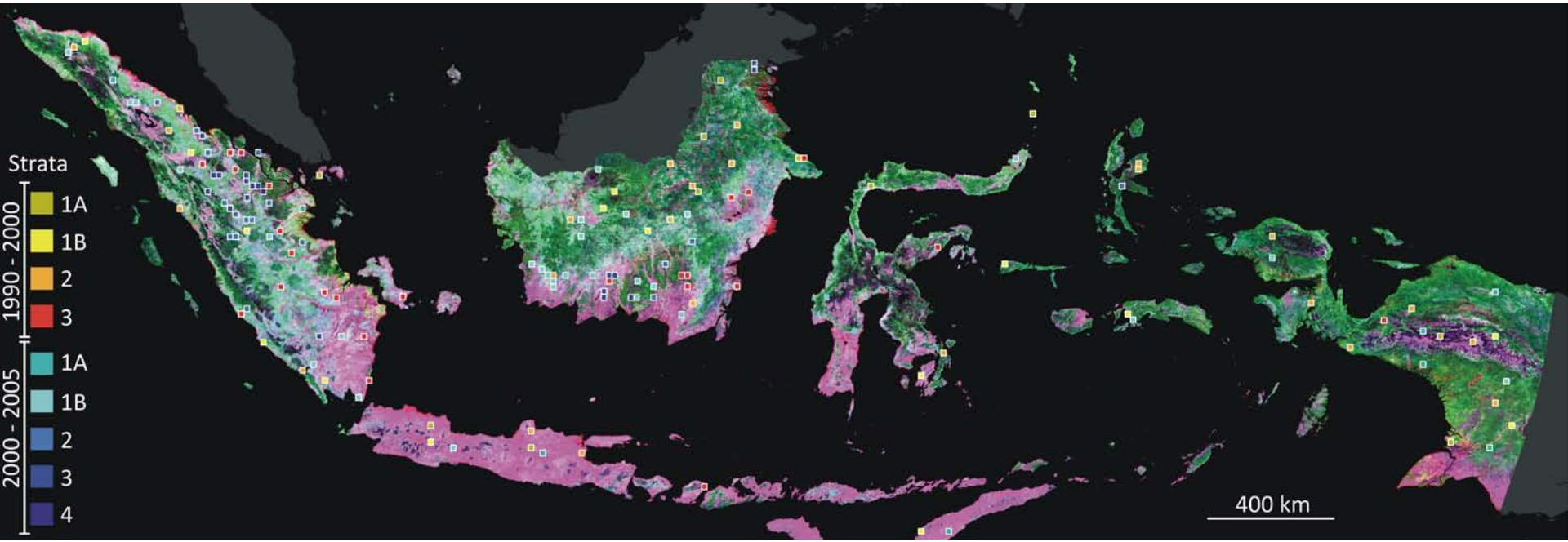

0°
70°N
60°N
50°N
40°N
500 km
Year 2000 forest cover fraction:
<10%
10-25%
25-50%
50-75%
>75%
70°N
60°N
50°N
40°N
Forest cover loss fraction, 2000-2005:
<1.5%
1.5-5.0%
5.0-10.0%
>10.0%
70°N
60°N
50°N
40°N
Burned forest fraction of total forest cover loss area:
<25%
25-50%
50-70%
>75%
(only within blocks with forest cover loss fraction above 1.5%)
SDSU

Biome-wide forest cover loss area estimation, 2000-2005

	Boreal	Temperate	Humid Tropics	Dry Tropics
Biome area in Mha	**2,150.9**	**1,787.8**	**1,962.4**	**2,611.7**
Forest area 2000 in Mha	**872.3**	**526.5**	**1156.4**	**723.3**
Area of forest loss 2000-2005 in Mha	**35.1**	**18.4**	**27.2**	**20.37**
% Forest area 2000 lost	**4.02** **1.65 excluding fire**	**3.50**	**2.35**	**2.82**

SDSU

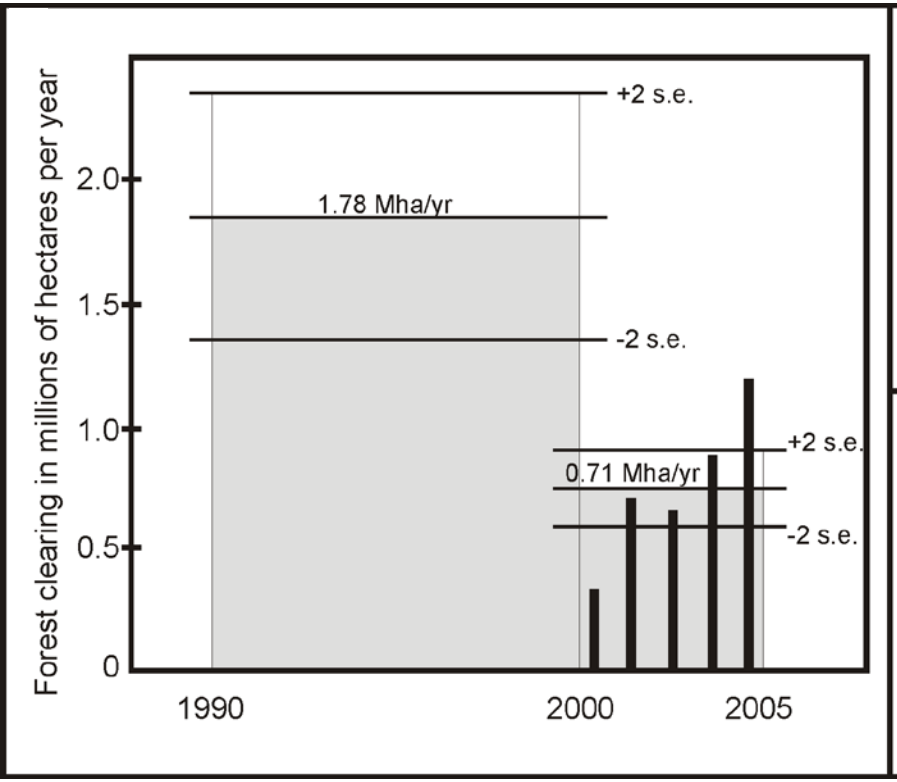
Quantifying changes in *rates* of forest clearing – Indonesian example

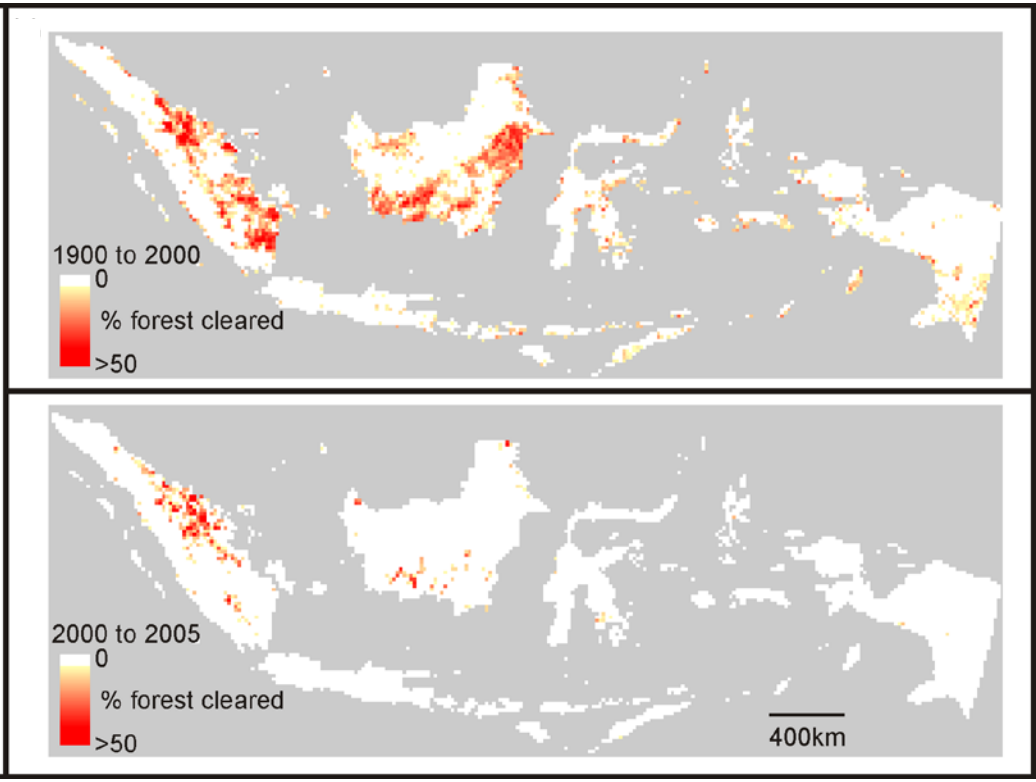


Using national-scale forest cover loss indicator maps
from AVHRR for 1990 to 2000 and
from MODIS for 2000 to 2005

SDSU

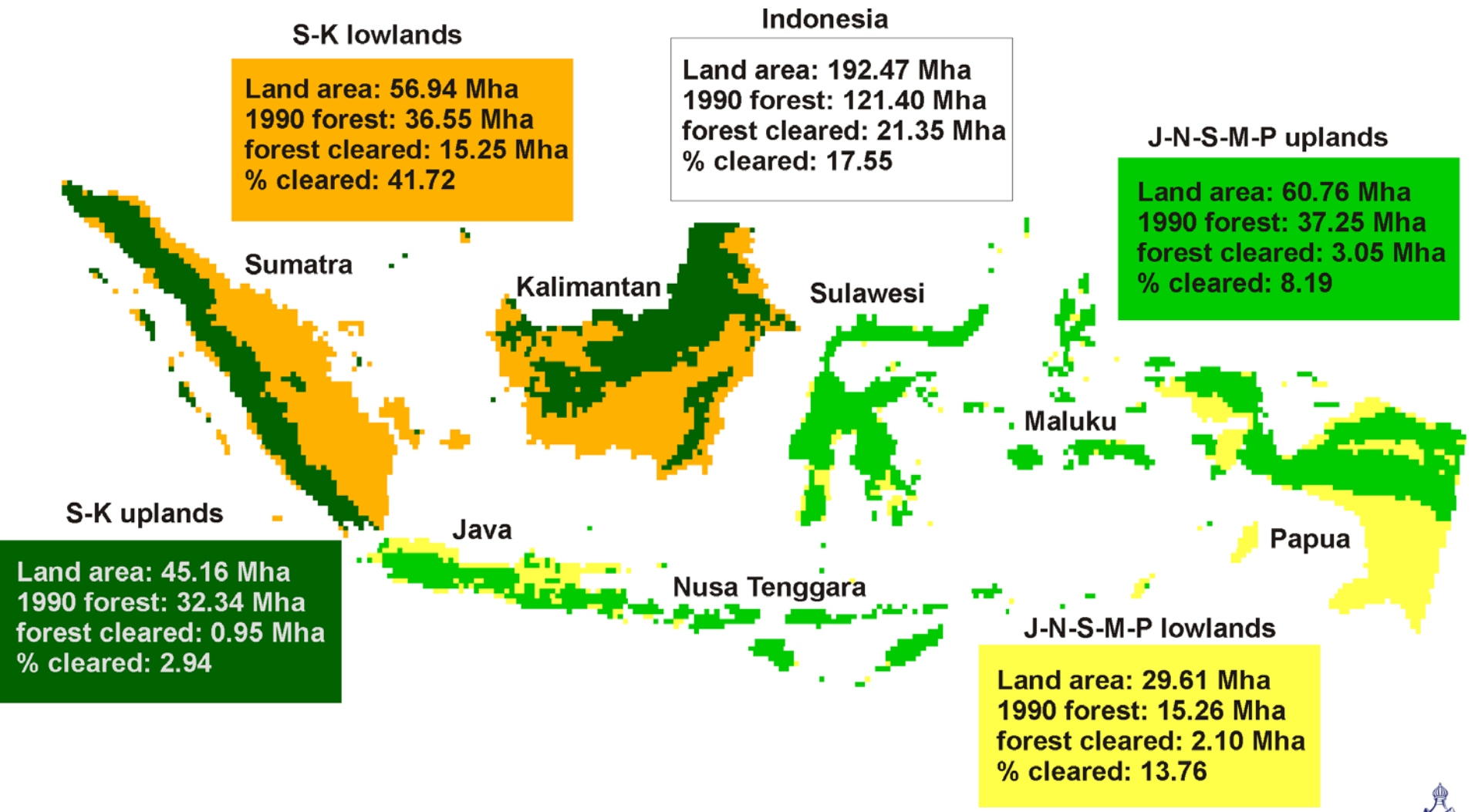
Indonesia forest clearing, 1990 to 2005





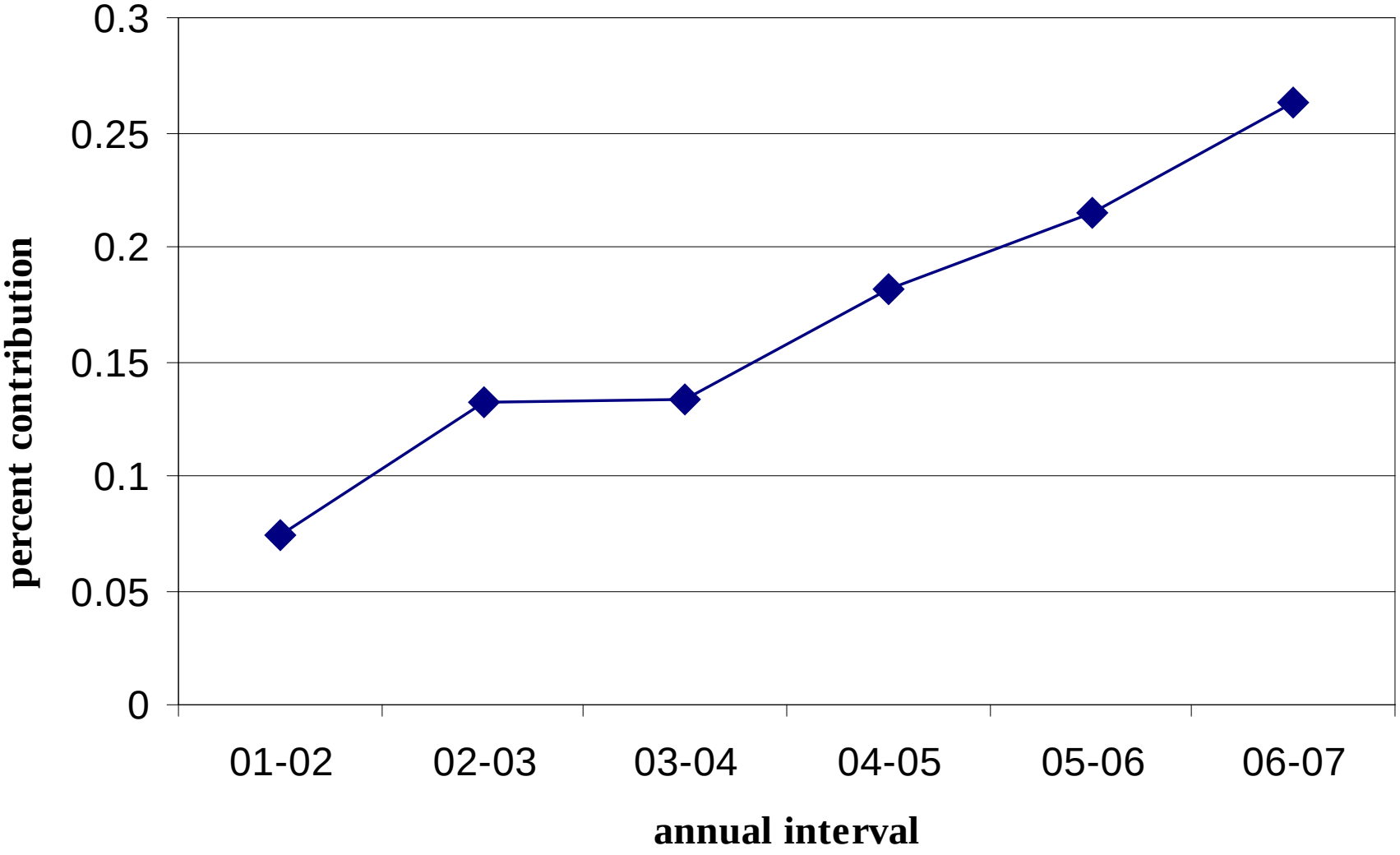
- 1990's
  - ENSO fires of 1997-98
  - Oil palm expansion
  - Stable central government and growing economy
- 2000
  - Economic crisis
  - Oil palm policy reform / slowed expansion
  - Less fire and easily accessible lowland forest

SDSU

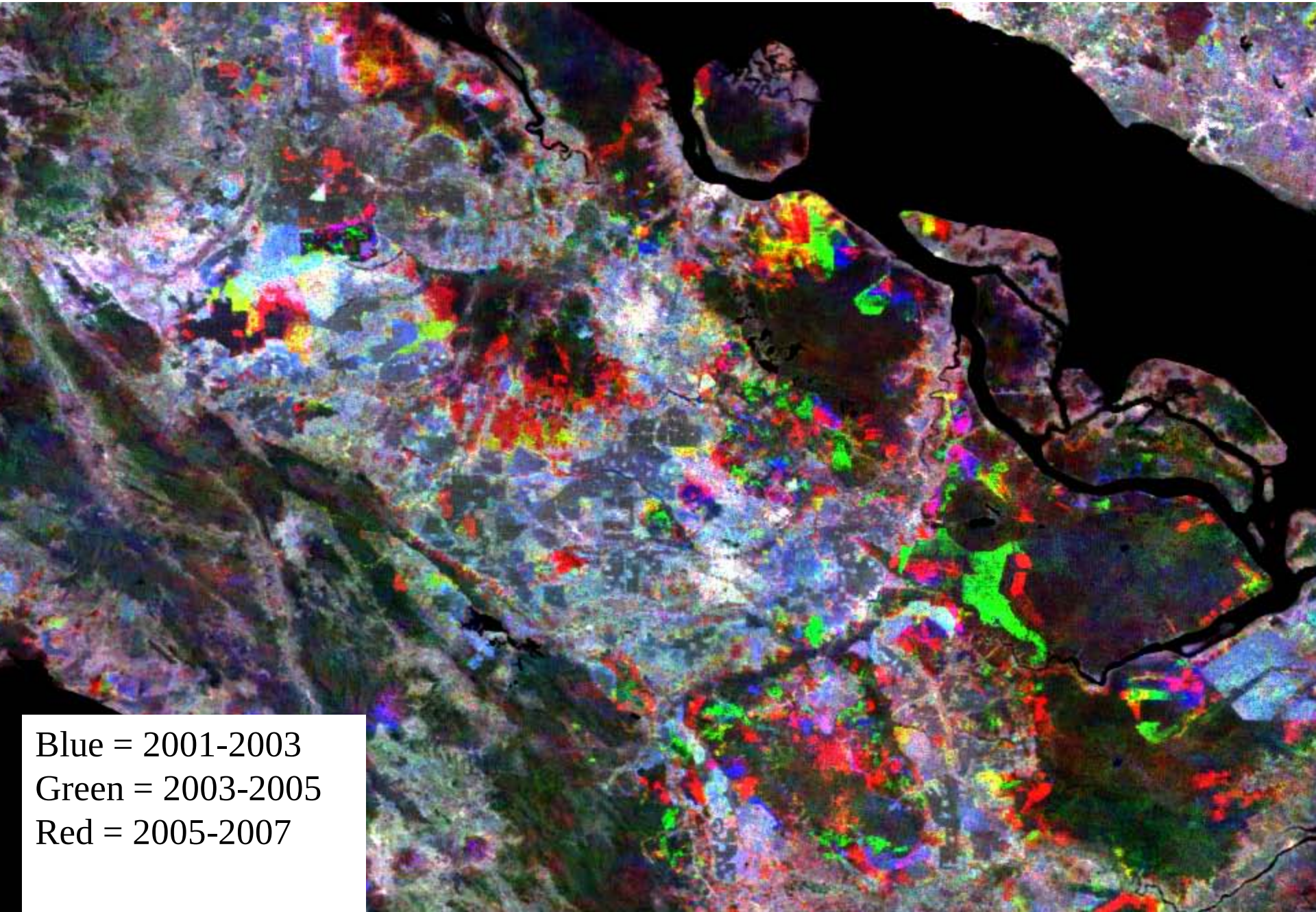

S-K lowlands
Land area: 56.94 Mha
1990 forest: 36.55 Mha
forest cleared: 15.25 Mha
% cleared: 41.72
Indonesia
Land area: 192.47 Mha
1990 forest: 121.40 Mha
forest cleared: 21.35 Mha
% cleared: 17.55
J-N-S-M-P uplands
Land area: 60.76 Mha
1990 forest: 37.25 Mha
forest cleared: 3.05 Mha
% cleared: 8.19
Sumatra
Kalimantan
Sulawesi
Maluku
Papua
Java
Nusa Tenggara
S-K uplands
Land area: 45.16 Mha
1990 forest: 32.34 Mha
forest cleared: 0.95 Mha
% cleared: 2.94
J-N-S-M-P lowlands
Land area: 29.61 Mha
1990 forest: 15.26 Mha
forest cleared: 2.10 Mha
% cleared: 13.76

SDSU

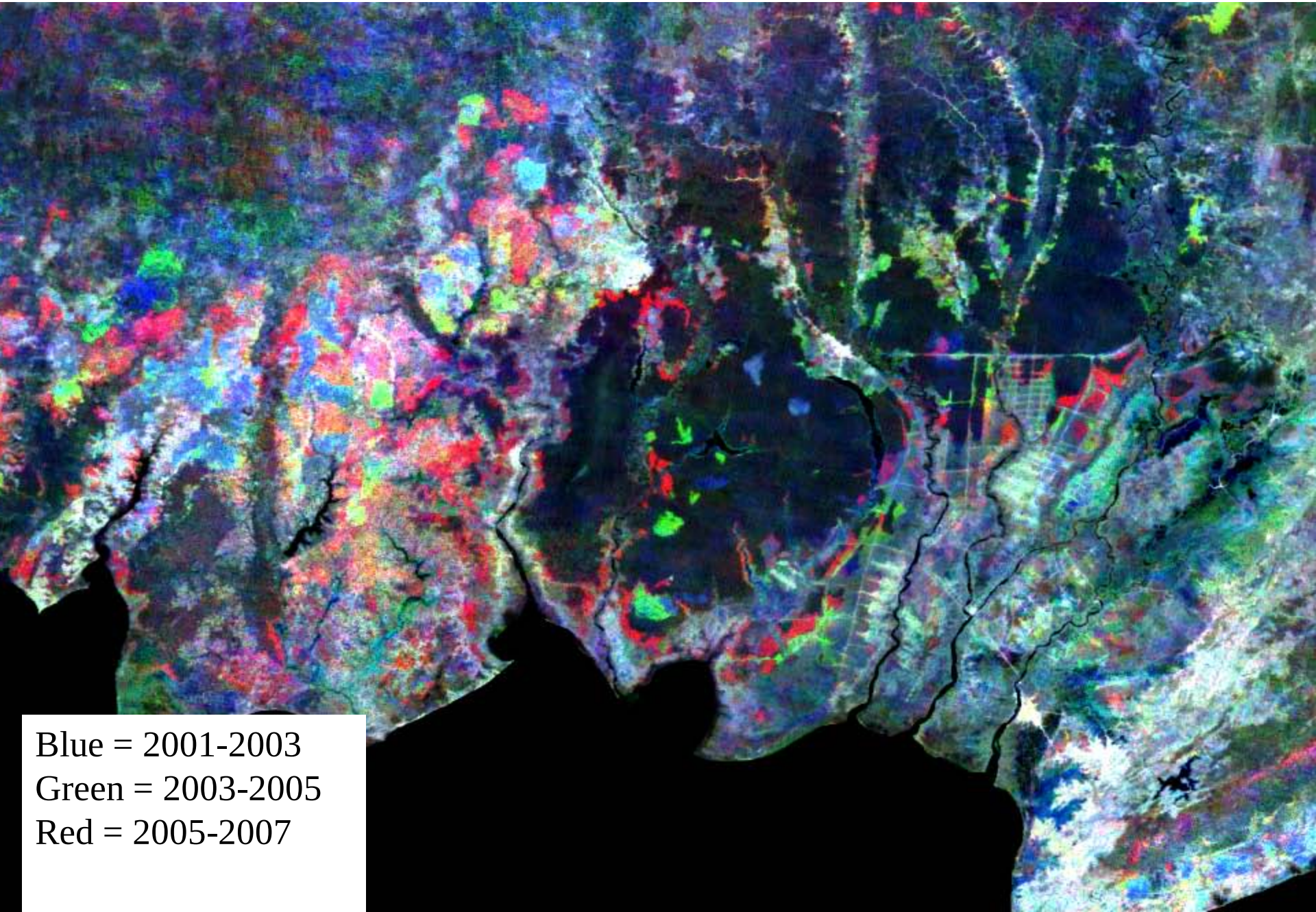
Trend in MODIS hotspots, 2001-2007



Change in Riau



Change in Kalimantan Tengah

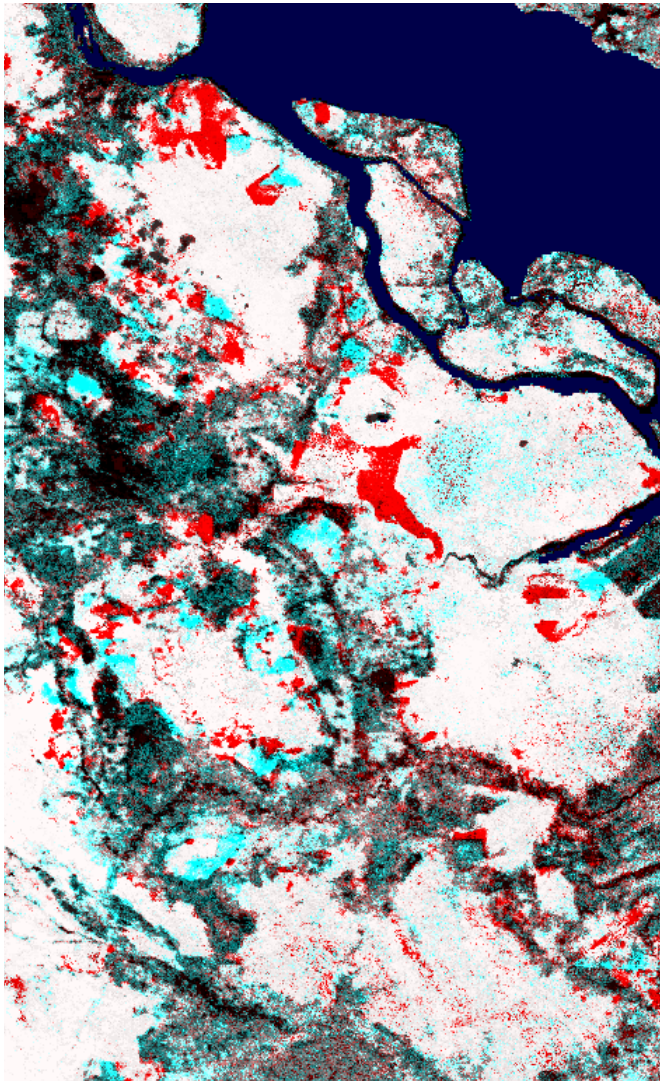


Change in tree cover for Riau, Sumatra

2000-2004

red = loss

cyan = gain



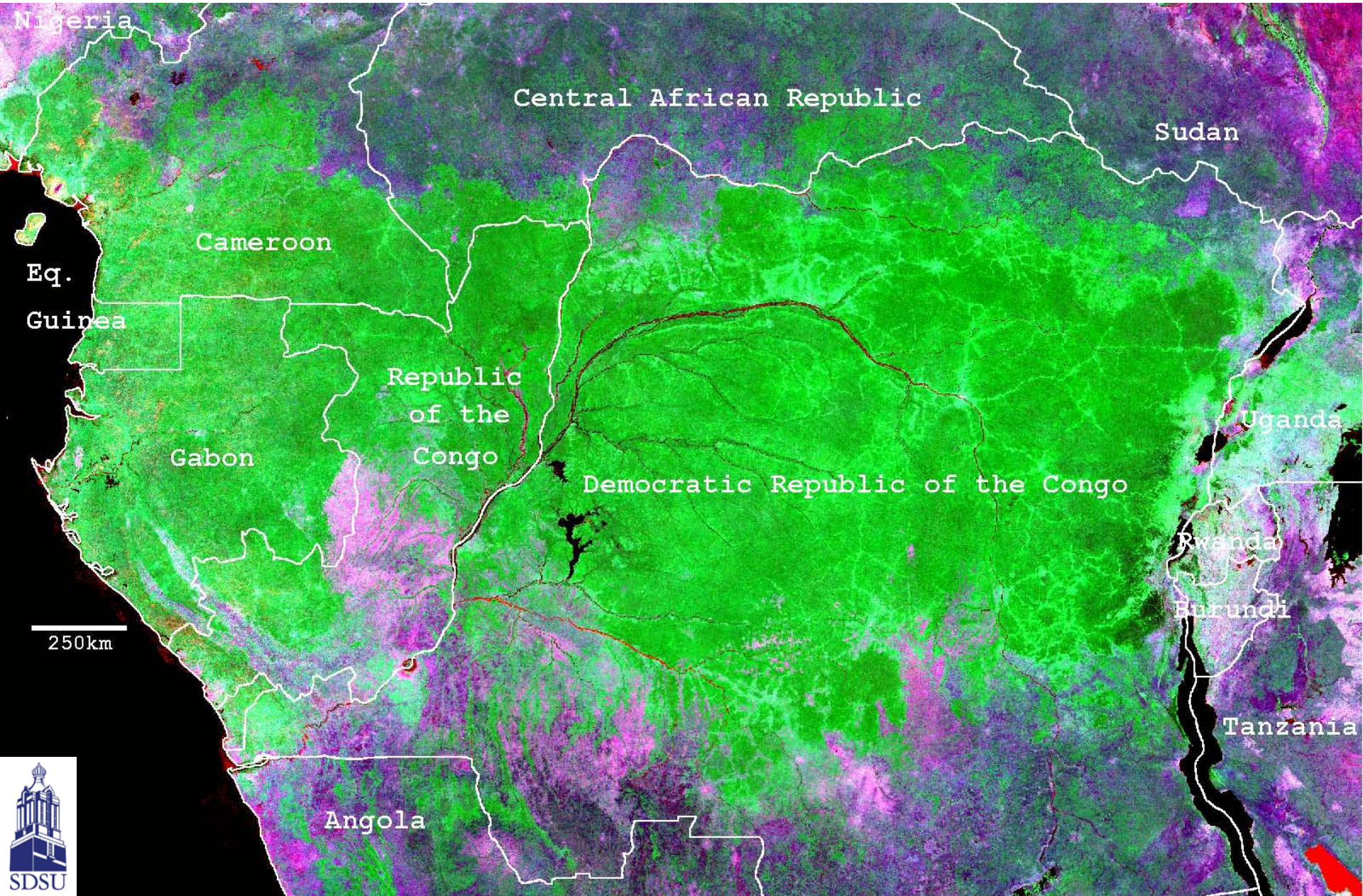
50 km

Percent Tree Cover

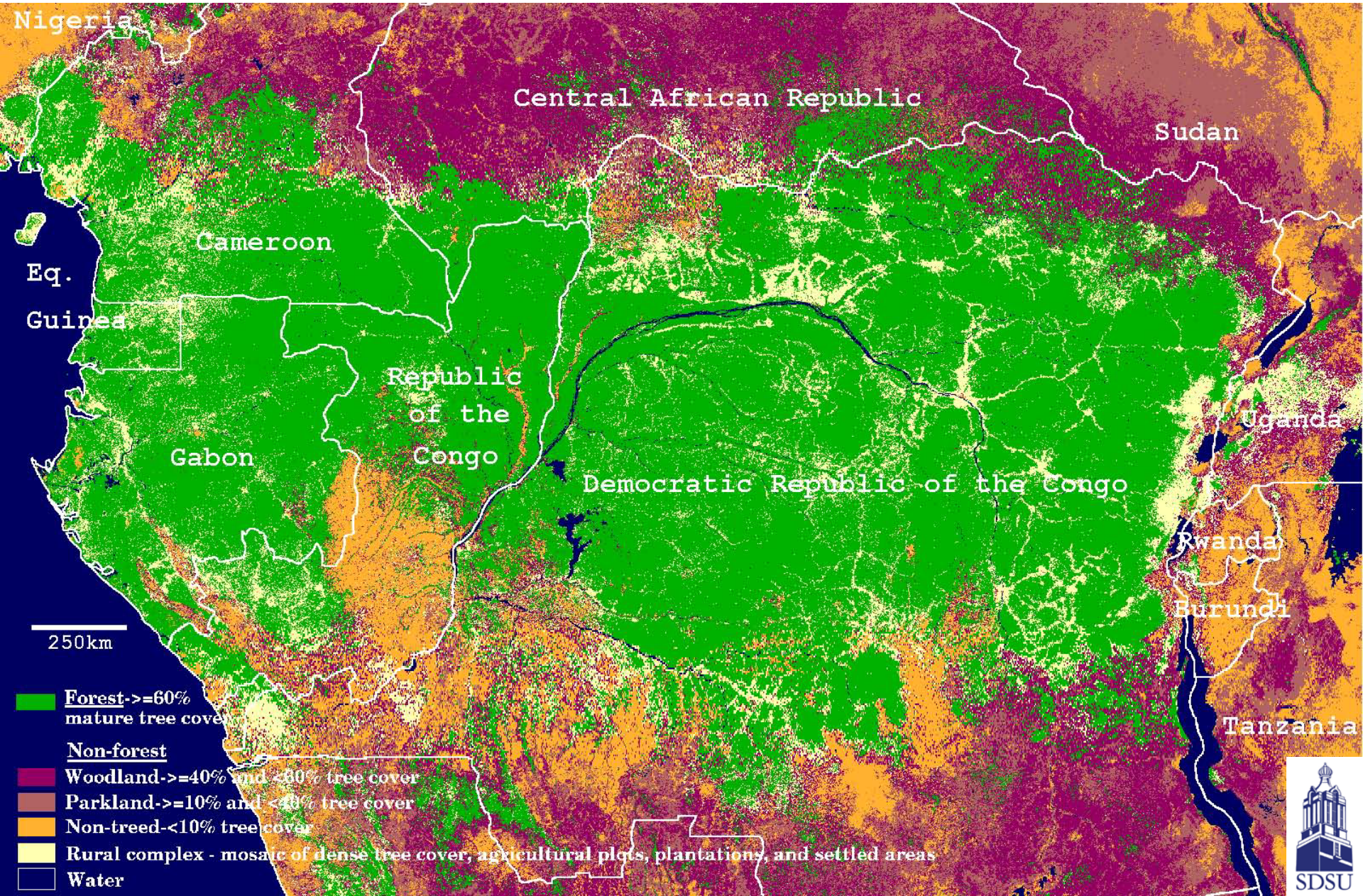
100

0

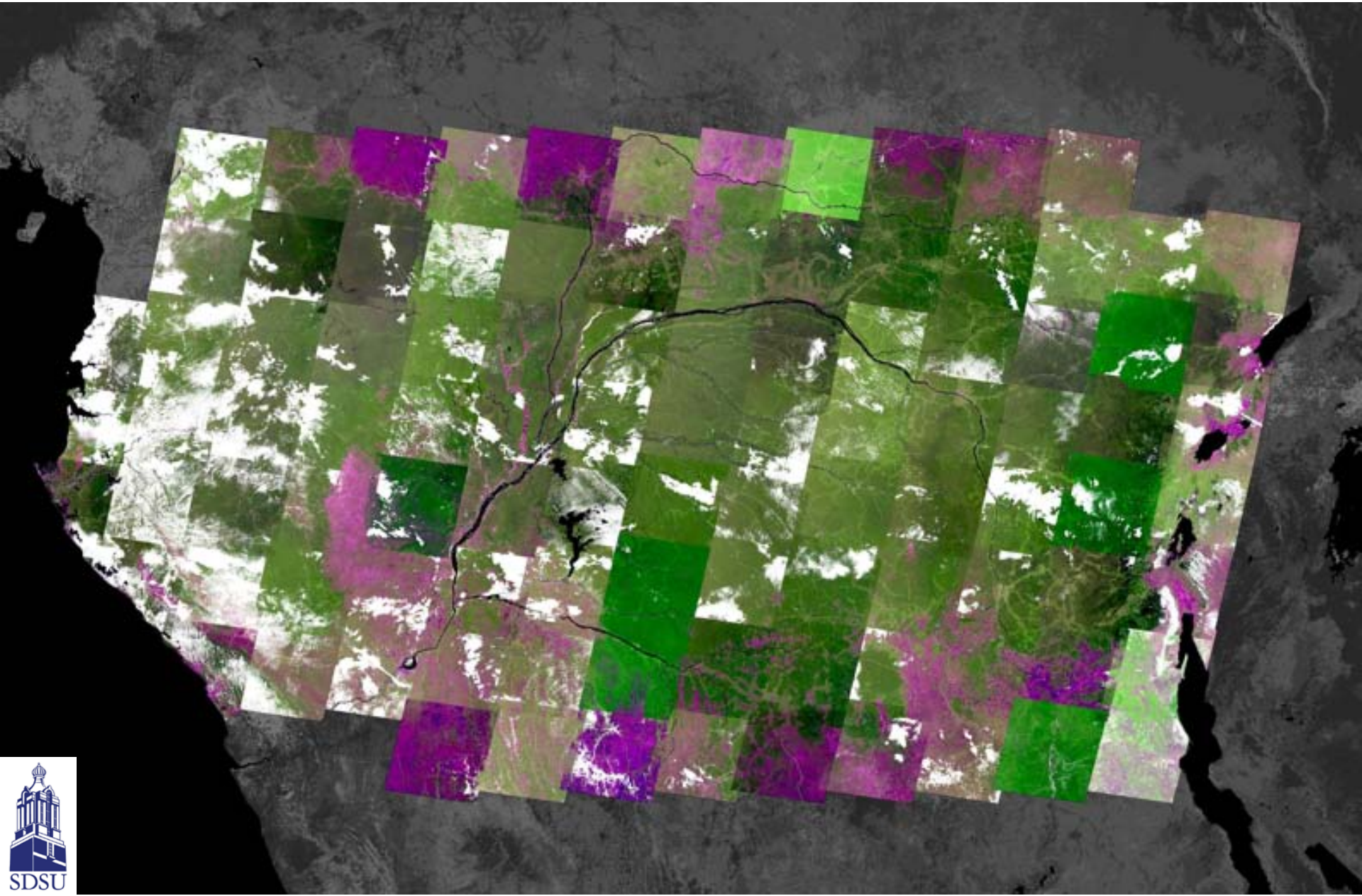
MODIS time-series data sets



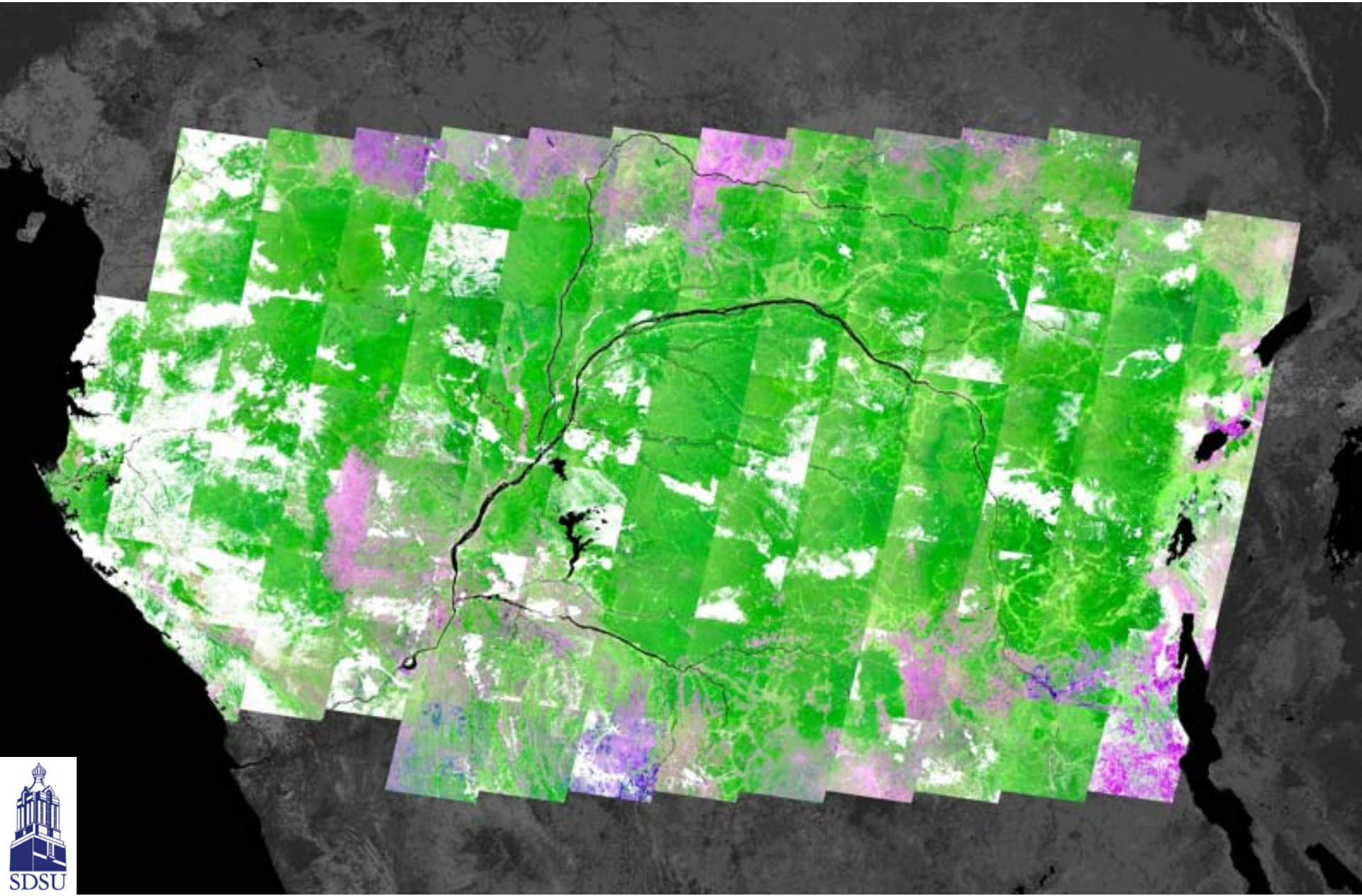
MODIS forest cover



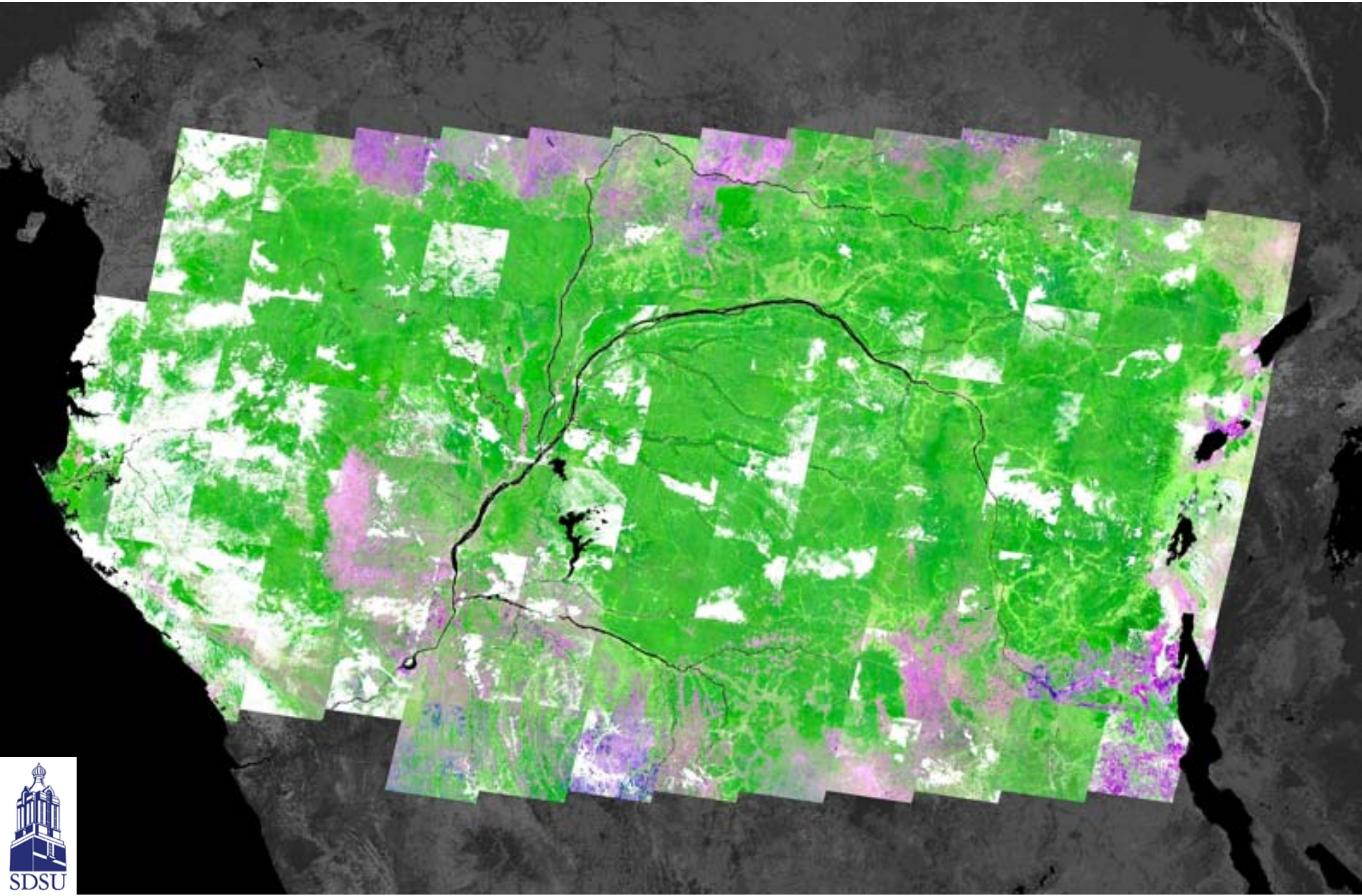
2000 Geocover



DOS-adjusted

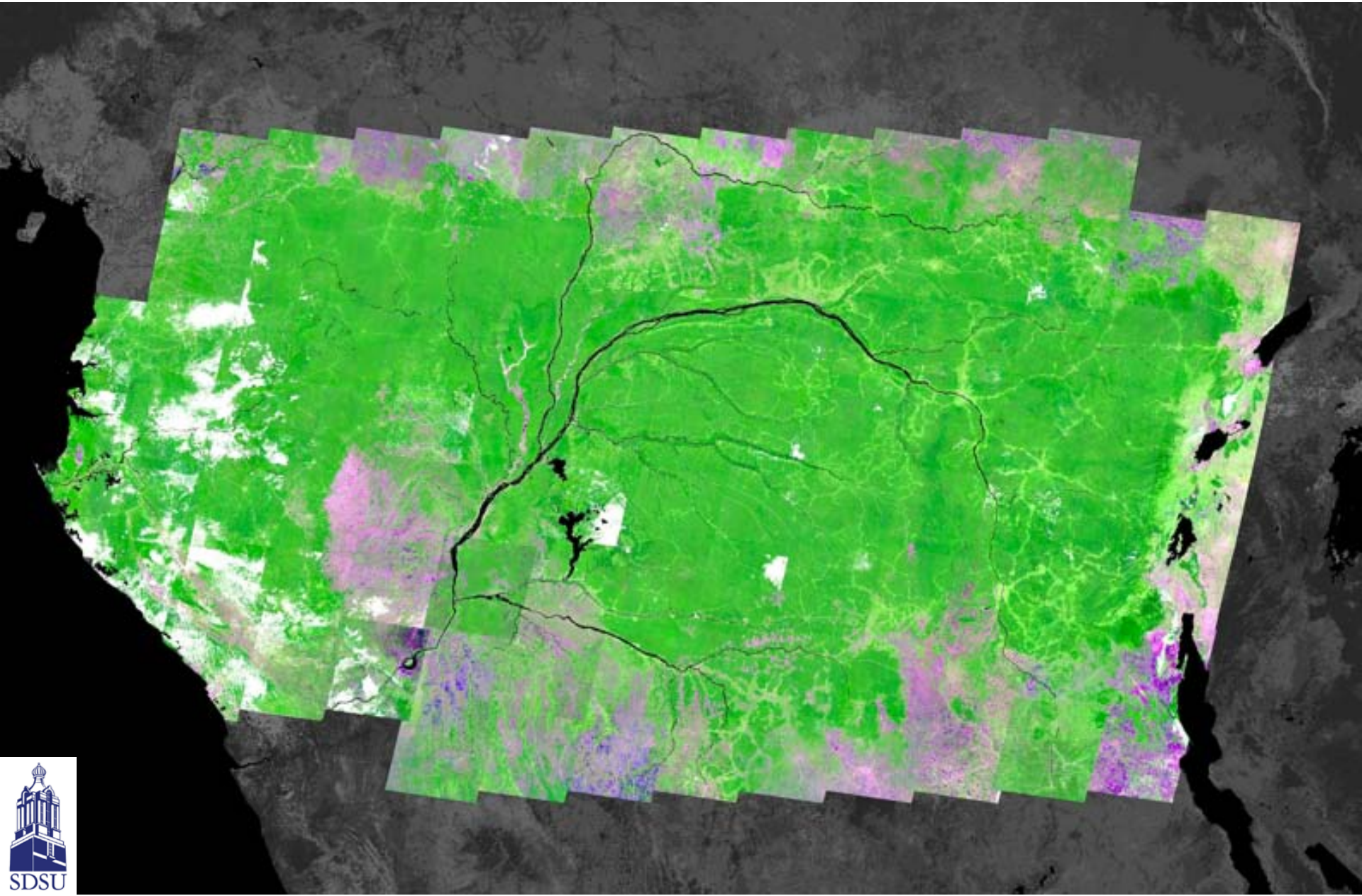


Anisotropy-adjusted



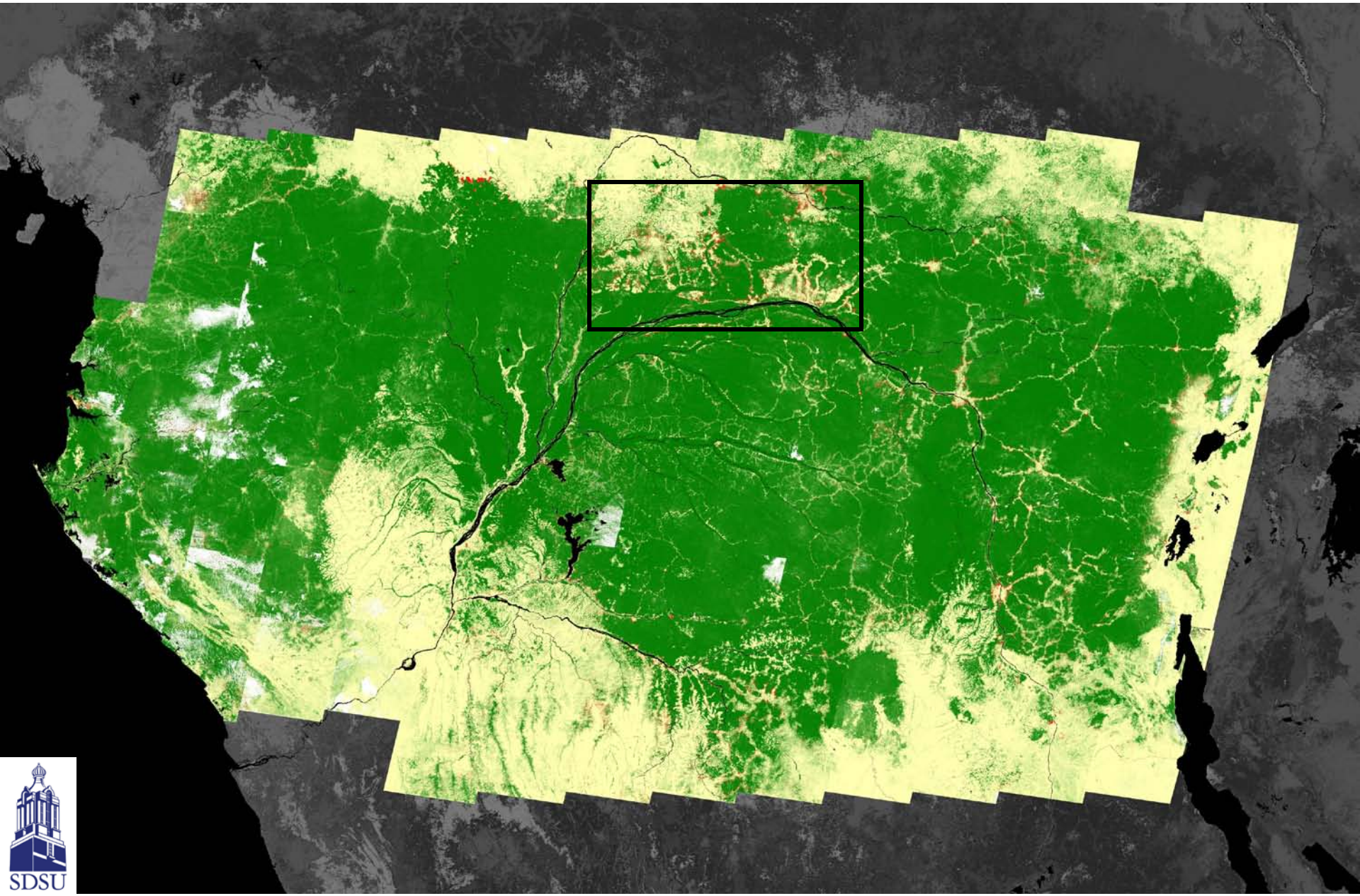
SDSU

3-5 image inputs per path/row



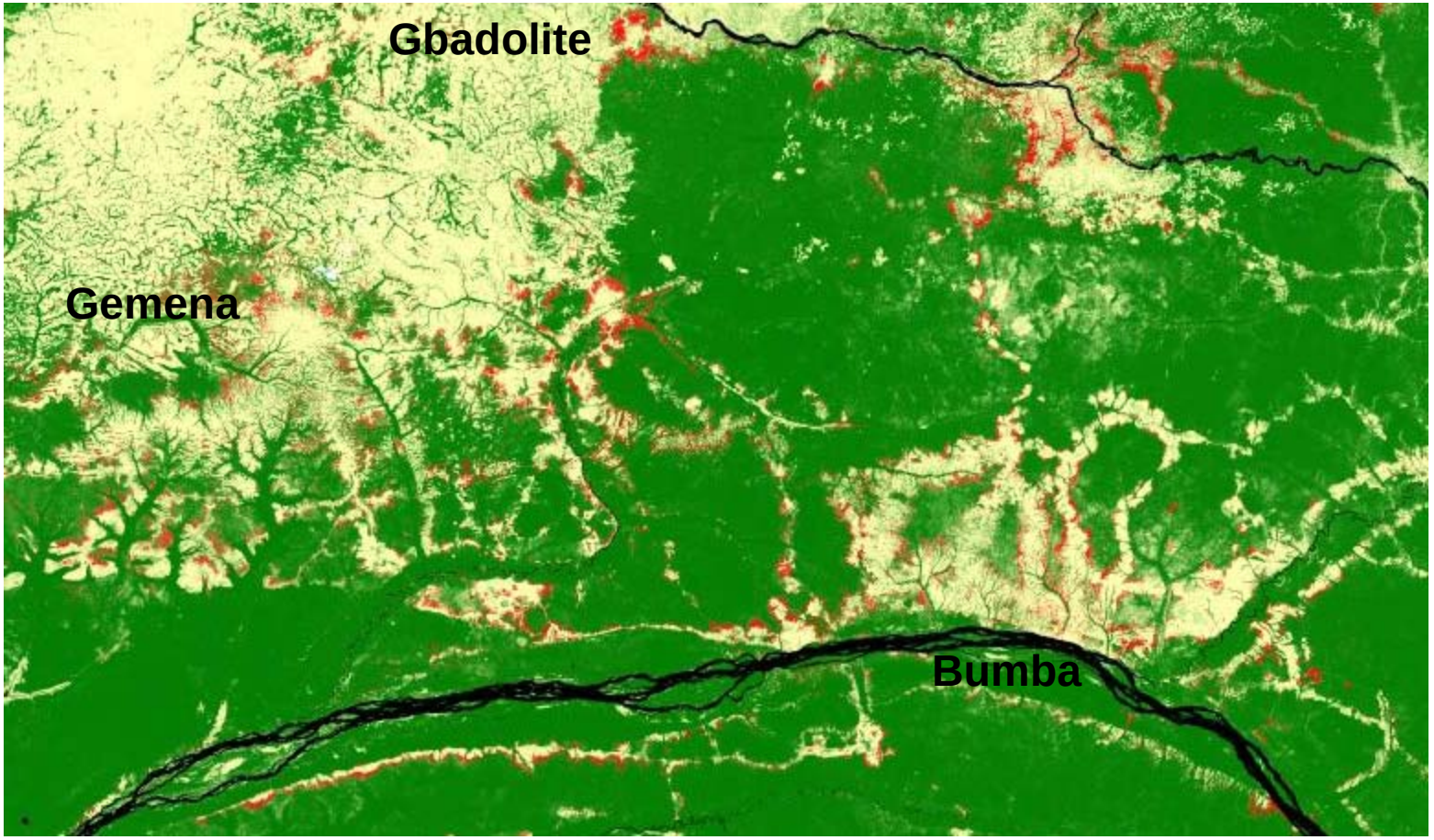
SDSU

Landsat forest cover and change

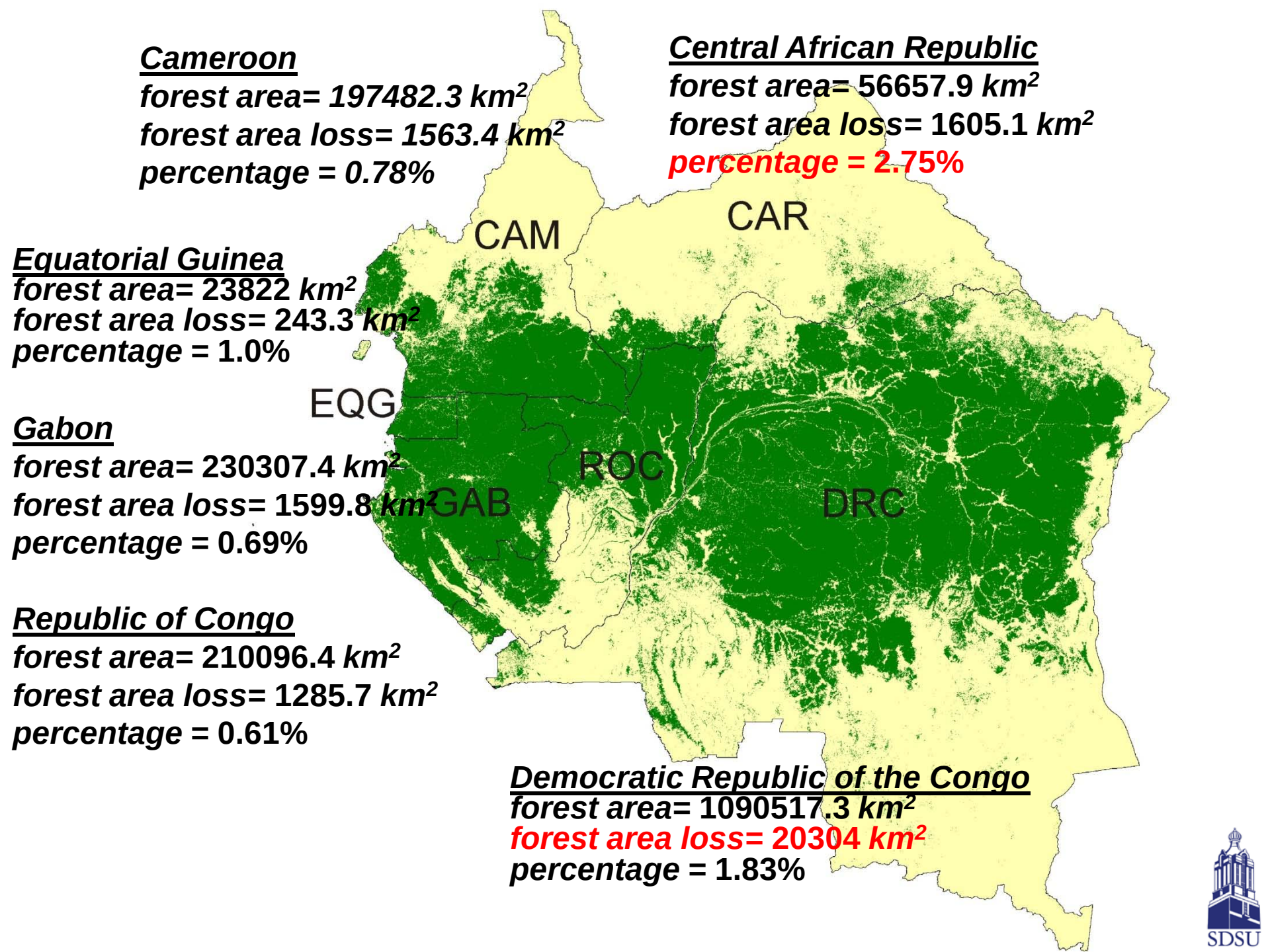


SDSU

Full-resolution



SDSU



Cameroon
forest area= 197482.3 km²
forest area loss= 1563.4 km²
percentage = 0.78%

Central African Republic
forest area= 56657.9 km²
forest area loss= 1605.1 km²
percentage = 2.75%

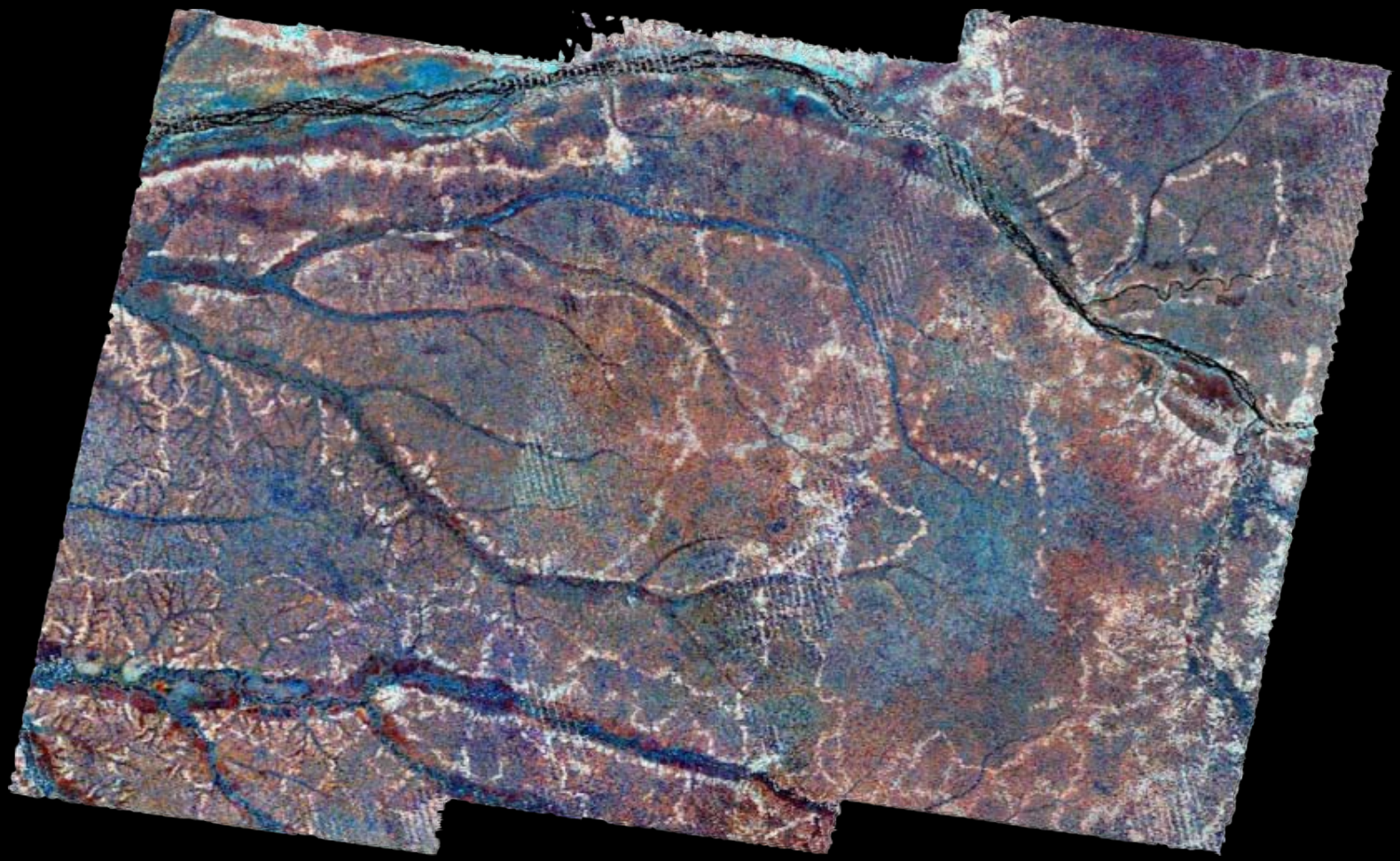
Equatorial Guinea
forest area= 23822 km²
forest area loss= 243.3 km²
percentage = 1.0%

Gabon
forest area= 230307.4 km²
forest area loss= 1599.8 km²
percentage = 0.69%

Republic of Congo
forest area= 210096.4 km²
forest area loss= 1285.7 km²
percentage = 0.61%

Democratic Republic of the Congo
forest area= 1090517.3 km²
forest area loss= 20304 km²
percentage = 1.83%

SDSU

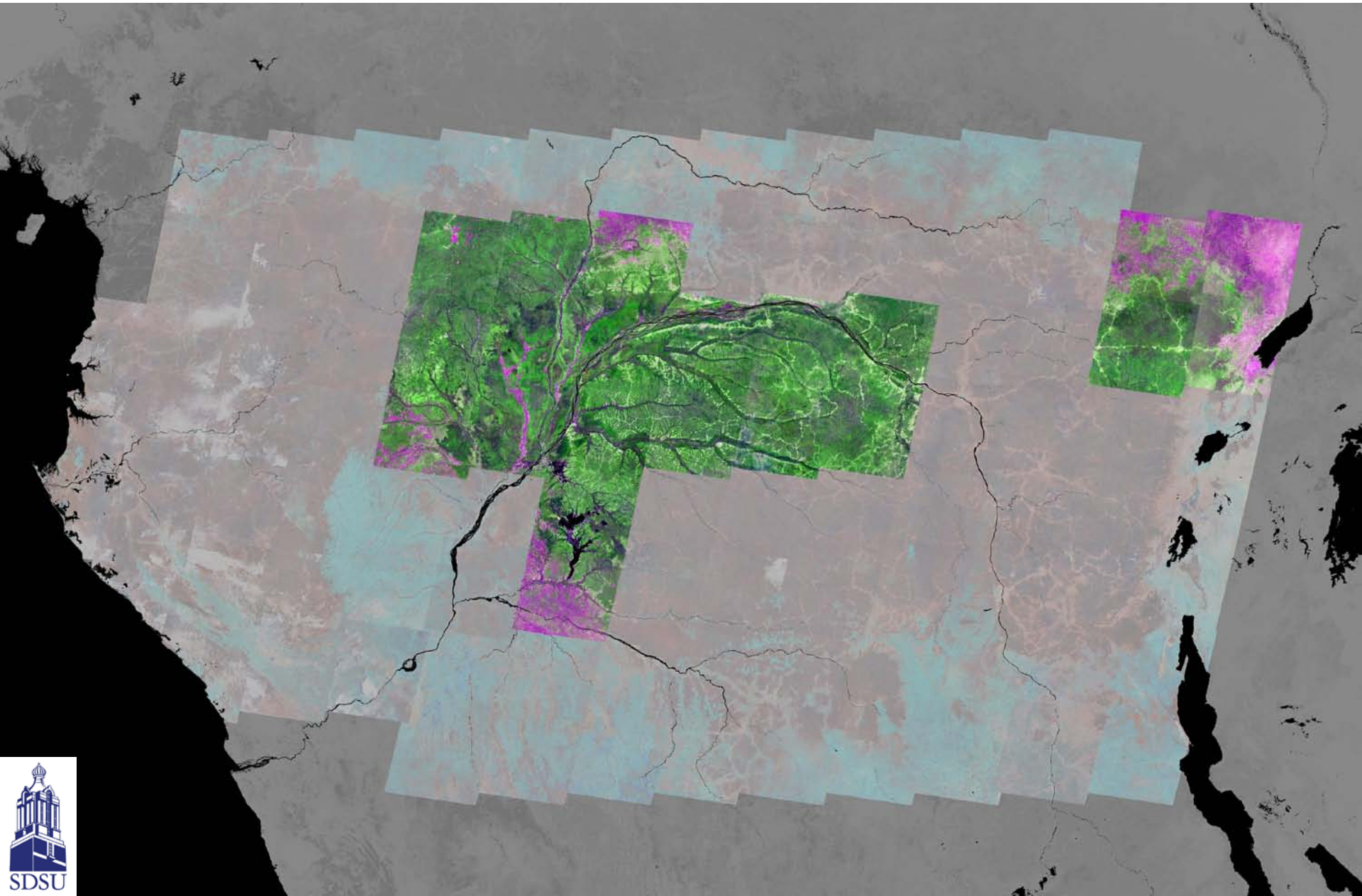


1 2 3 4 5

2005 epoch with SLC-off data

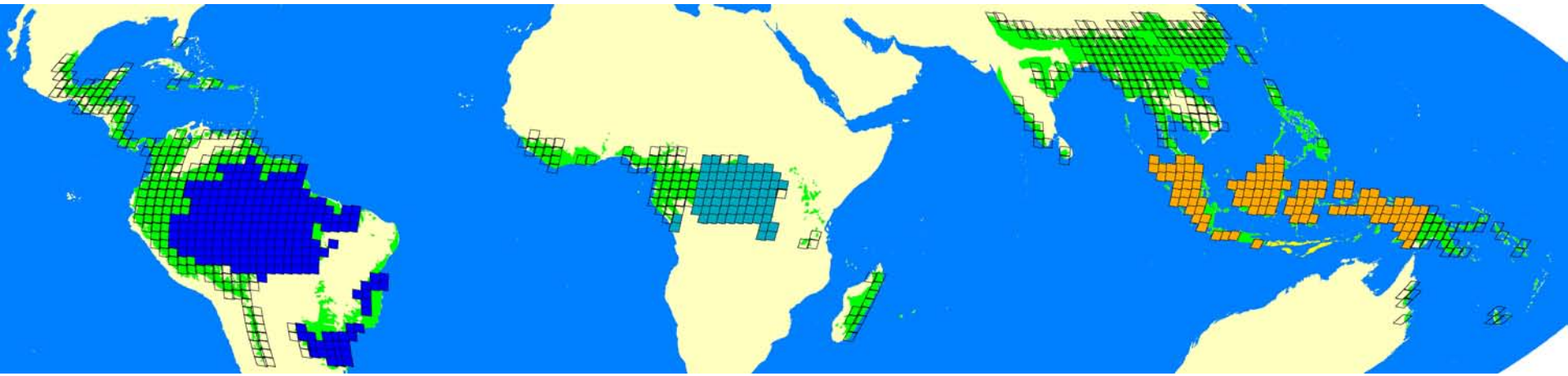
SDSU

Mid-decadal results – 2000 to 2005



SDSU

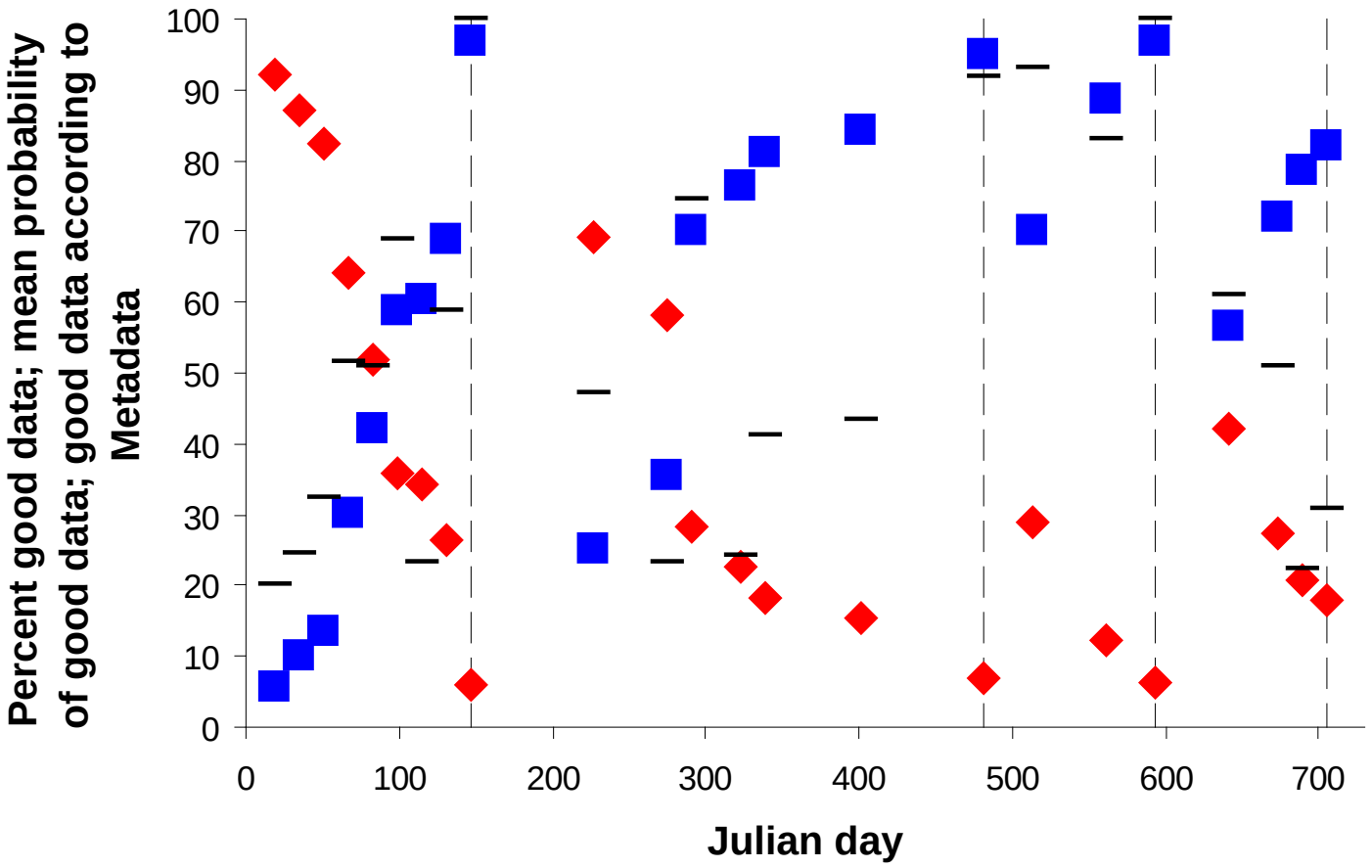
Study area 2000 to 2005 forest cover and change analysis



Green = humid tropical biome with Landsat footprints over areas with >10% forest cover with Brazil, DRC and Indonesia as priority countries

SDSU

Two years (2000 & 2001) of ETM+ for path/row 250/64
Blue is percent of good data in composite
Red is mean percent of bad data probability
Black bars show percent good data according to Metadata
for the images used in compositing
The vertical lines mark the reporting intervals (good data >=95%)



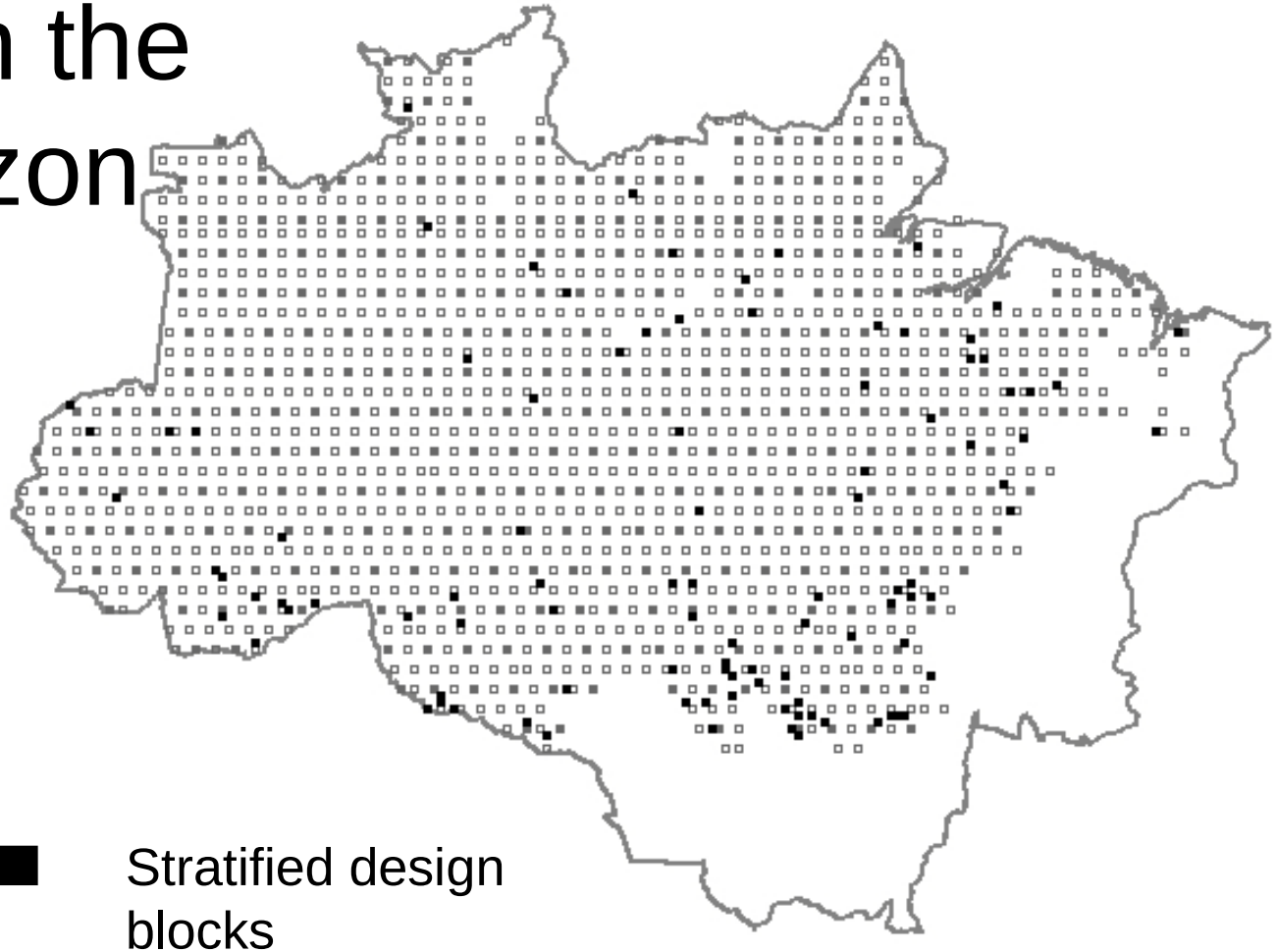
SDSU

Conclusions

- Targeted sampling is efficient in quantifying forest cover and change at national and regional scales
- However, it cannot replace a map for many applications
- Exhaustive mapping is much more data intensive, and does not provide an uncertainty estimate
- However, the fine-scale and spatial explicitness of map products is required for many applications
- Methods for automatically processing per pixel assessments for mapping at Landsat-scale are viable
- The open archive at USGS will enable the determination of monitoring capabilities given a single Landsat instrument

SDSU

Sampling in the Legal Amazon



Stratified design blocks

Systematic design (1 degree) blocks

Additional (0.5 degree) systematic design blocks

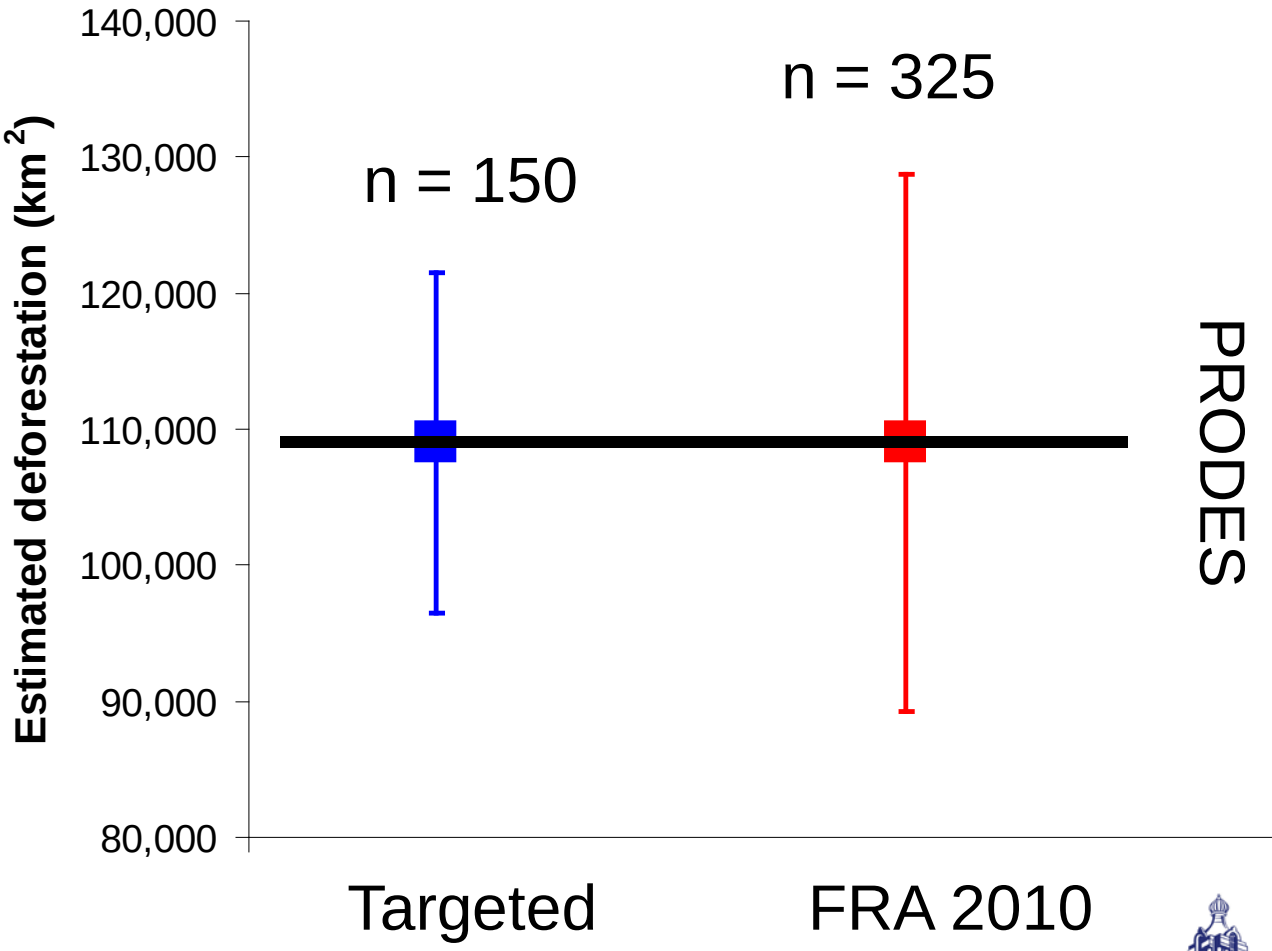
BLA

0 500 1,000 2,000 km

SDSU

Comparing different sampling methods to estimate PRODES change

The targeted design is **more precise and efficient** than the FRA 2010 design



SDSU