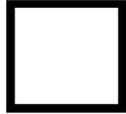


Global land cover mapping

1994 - 111km

1998 - 8 km

2000 - 1 km



2002 - 0.5 km



2006 - 0.25 km



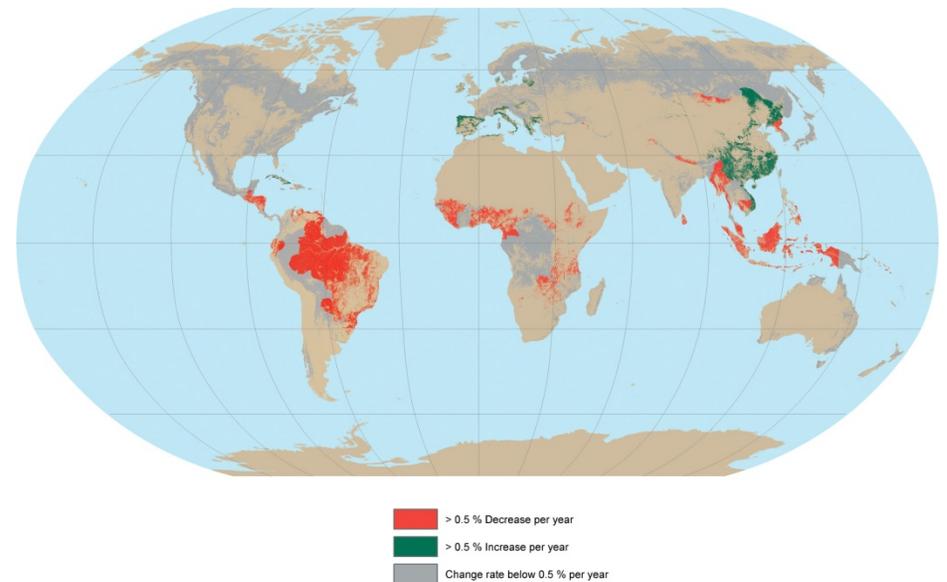
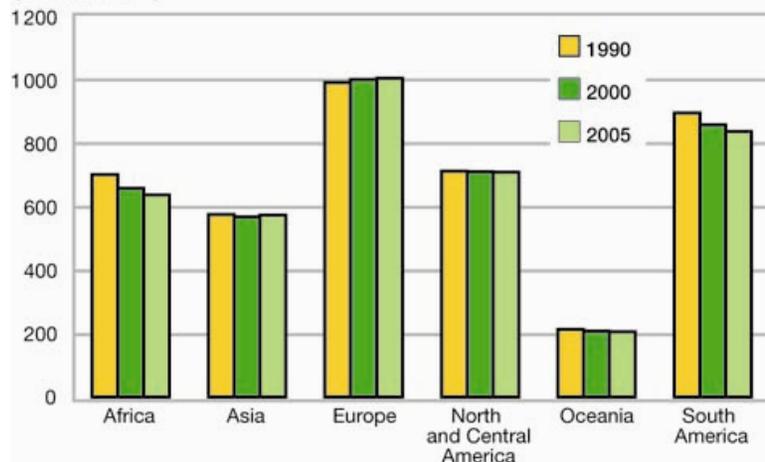
2010 - 0.03 km



2005 United Nations Food and Agriculture Organization Forest Resource Assessment Report

- Africa and South America feature largest forest losses
- Overall rate of forest loss continues to decrease

Trends in forest area by region, 1990–2005
(million ha)



Data requirements for global forest monitoring

- Systematic global acquisitions
- No/low cost
- Easy access
- Minimal pre-processing required

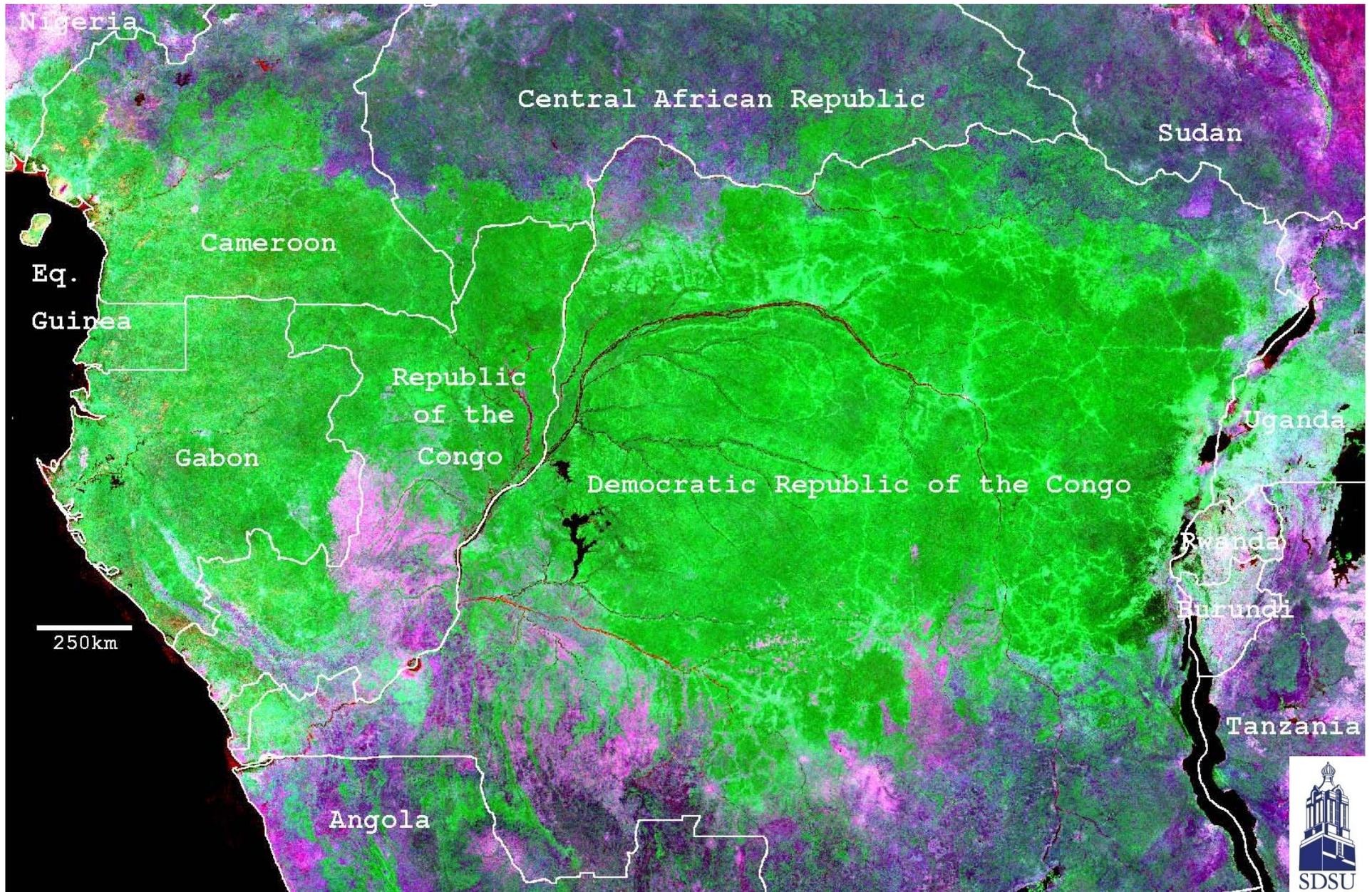
Monitoring at national scales in the humid tropics – different situations

- Brazil
 - Large-scale change, most of which is located in seasonally cloud-free region, deforestation
- Indonesia
 - Large-scale change, occurring in persistently cloud-affected region, much topography, active forestry
- Democratic Republic of Congo
 - Fine-scale change, occurring in persistently cloud-affected region

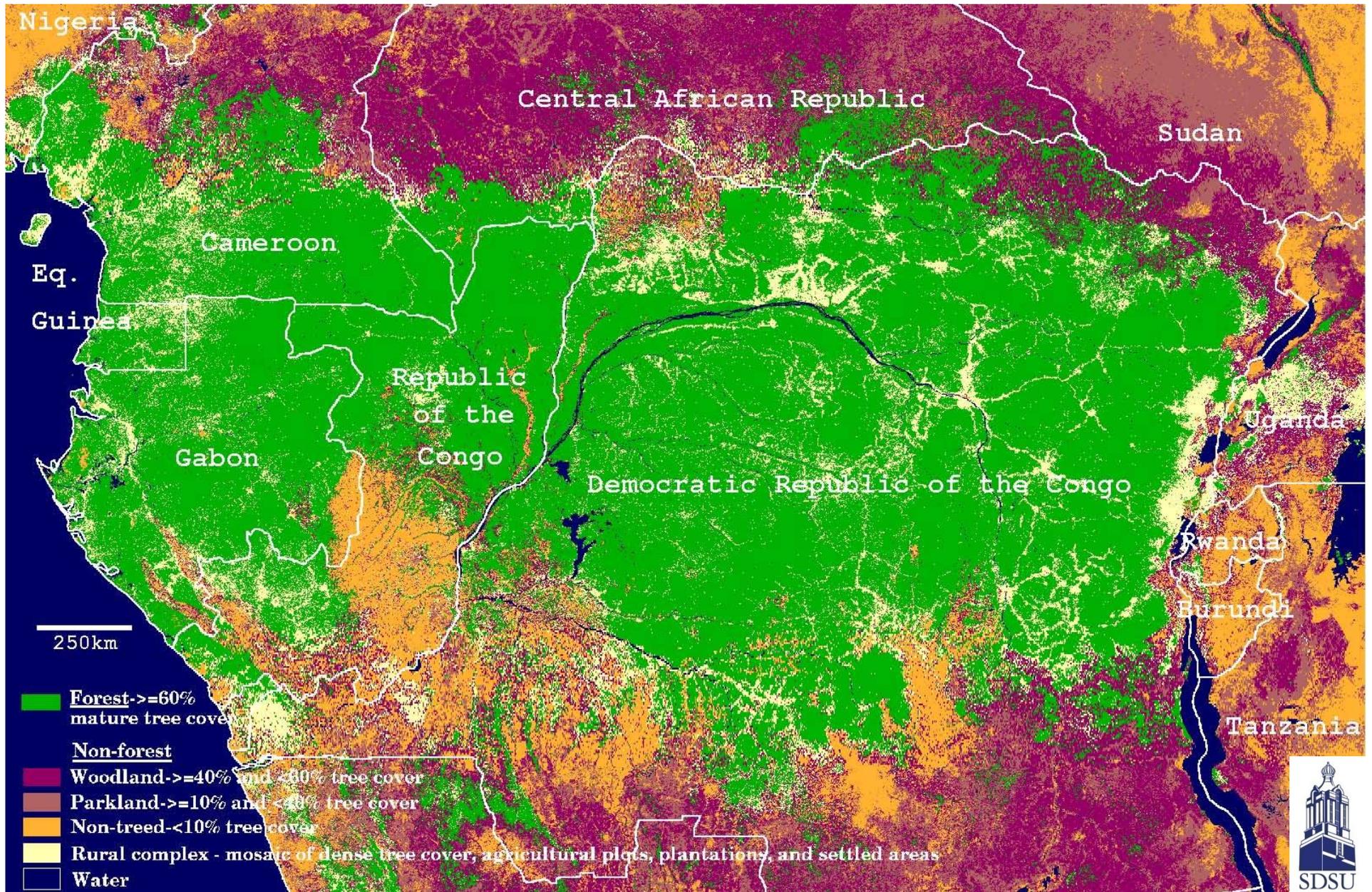
Mapping forest cover with Landsat

- Exhaustive mapping of forest cover and change using Landsat data
- Employs MODIS forest cover maps to pre-process Landsat imagery
- Apply dark object subtraction and cross-track anisotropy corrections to each input Landsat image
- Apply automated cloud and shadow models per pixel
- Use “good” observations to characterize forest cover and change with hard-wired algorithms
- Exhaustively mine the Landsat archive to quantify forest extent and change, starting with the ETM+ epoch (1999 to present)

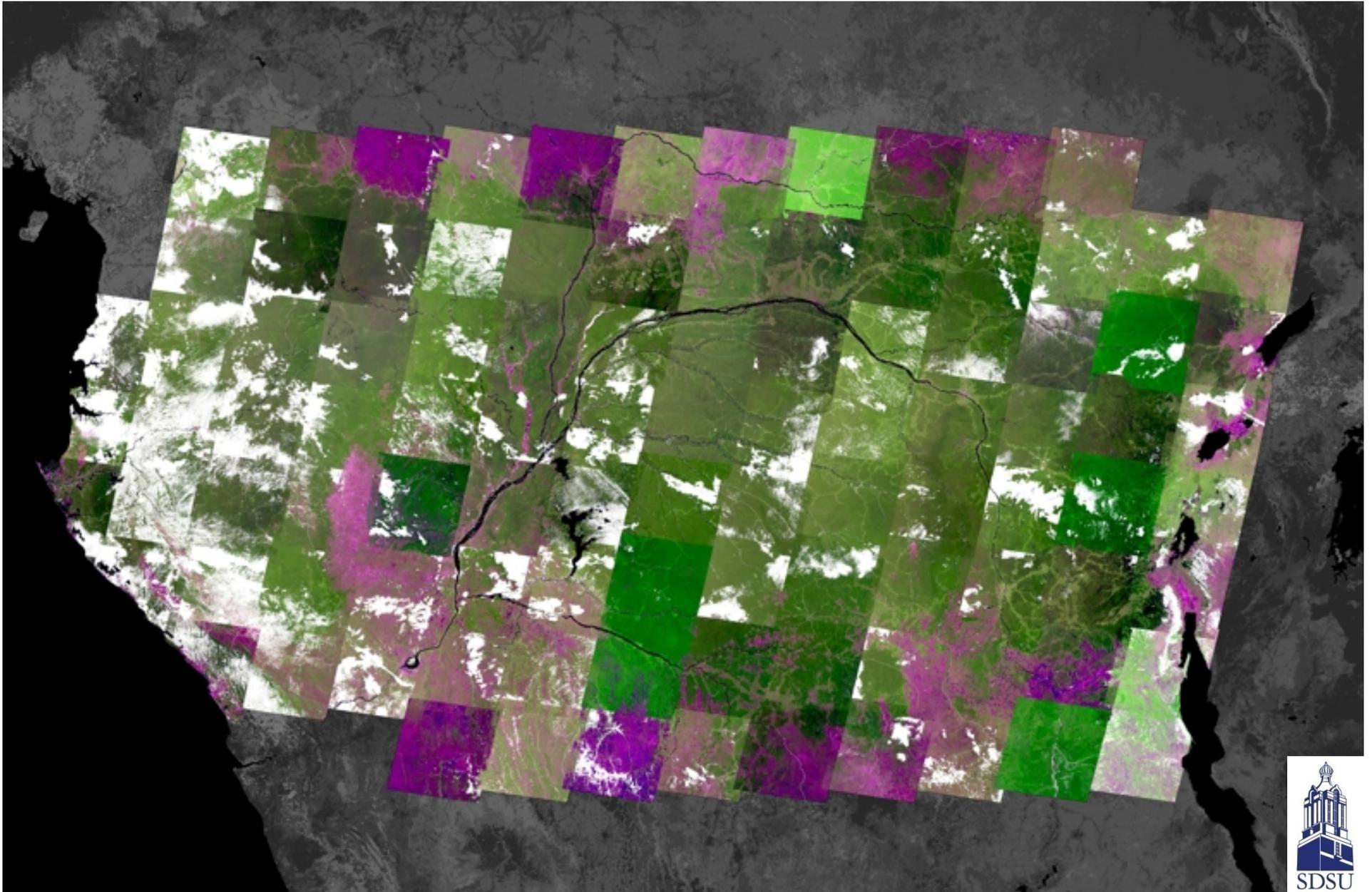
MODIS time-series inputs



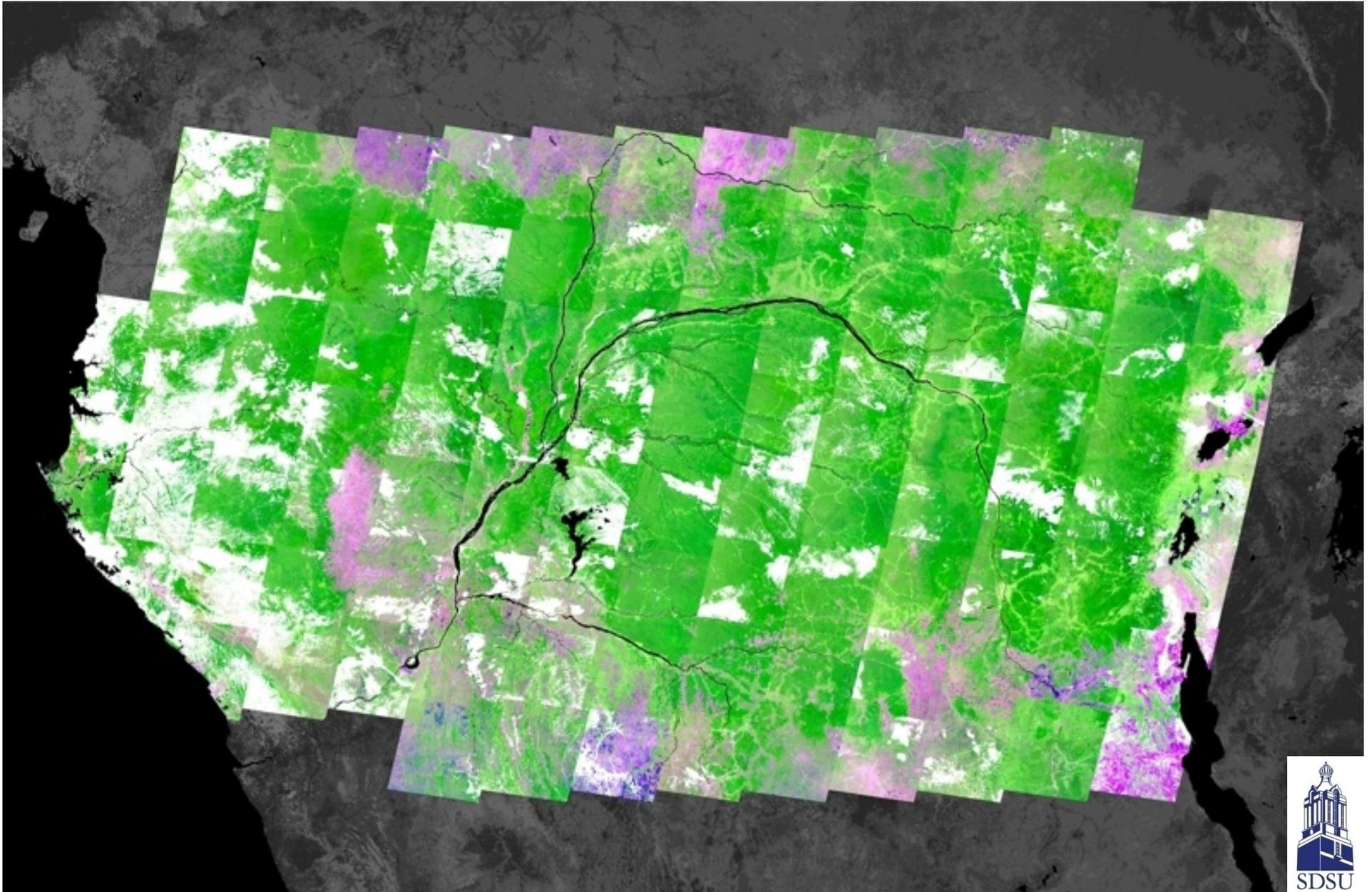
MODIS forest cover



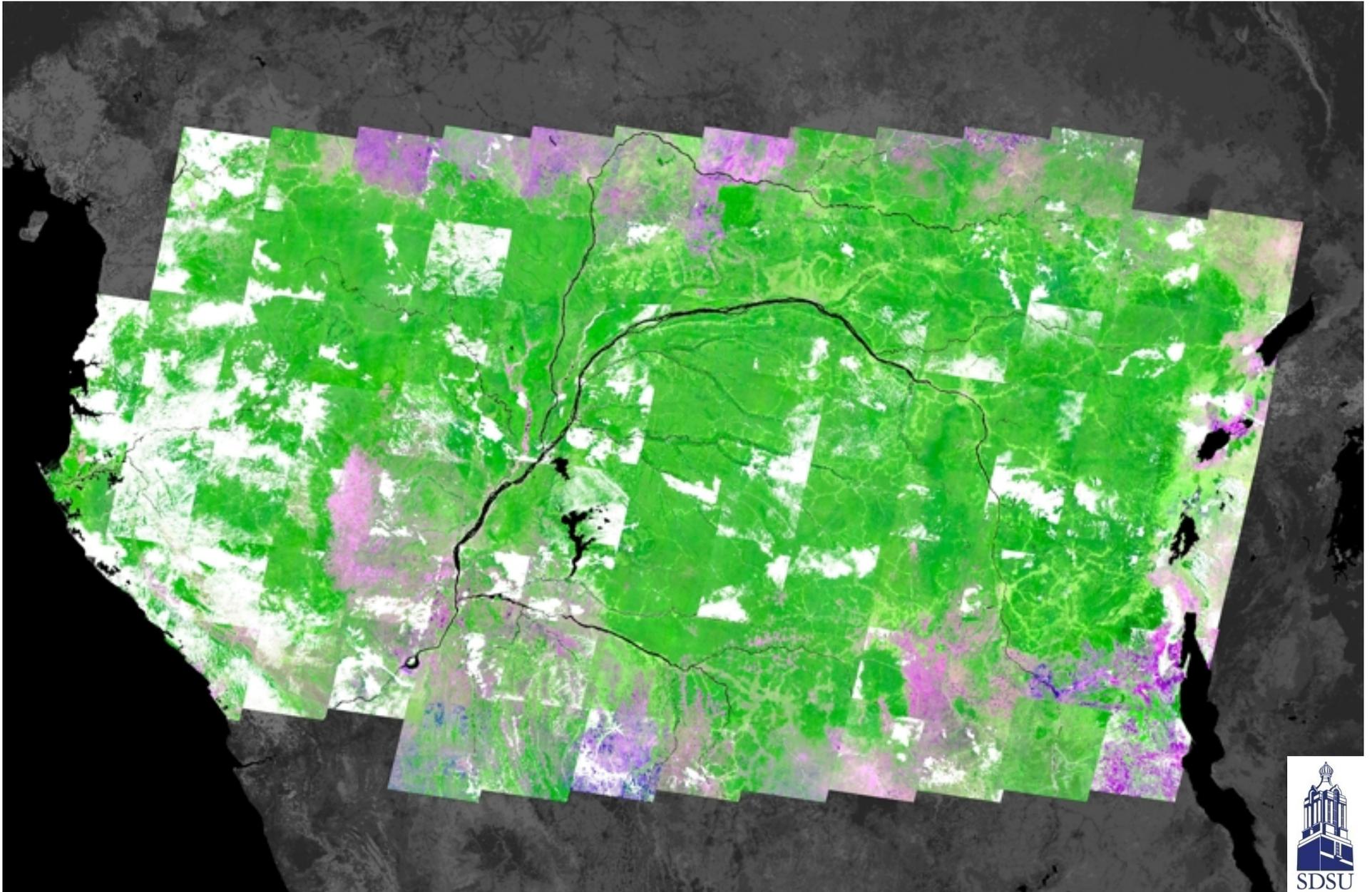
2000 GLS



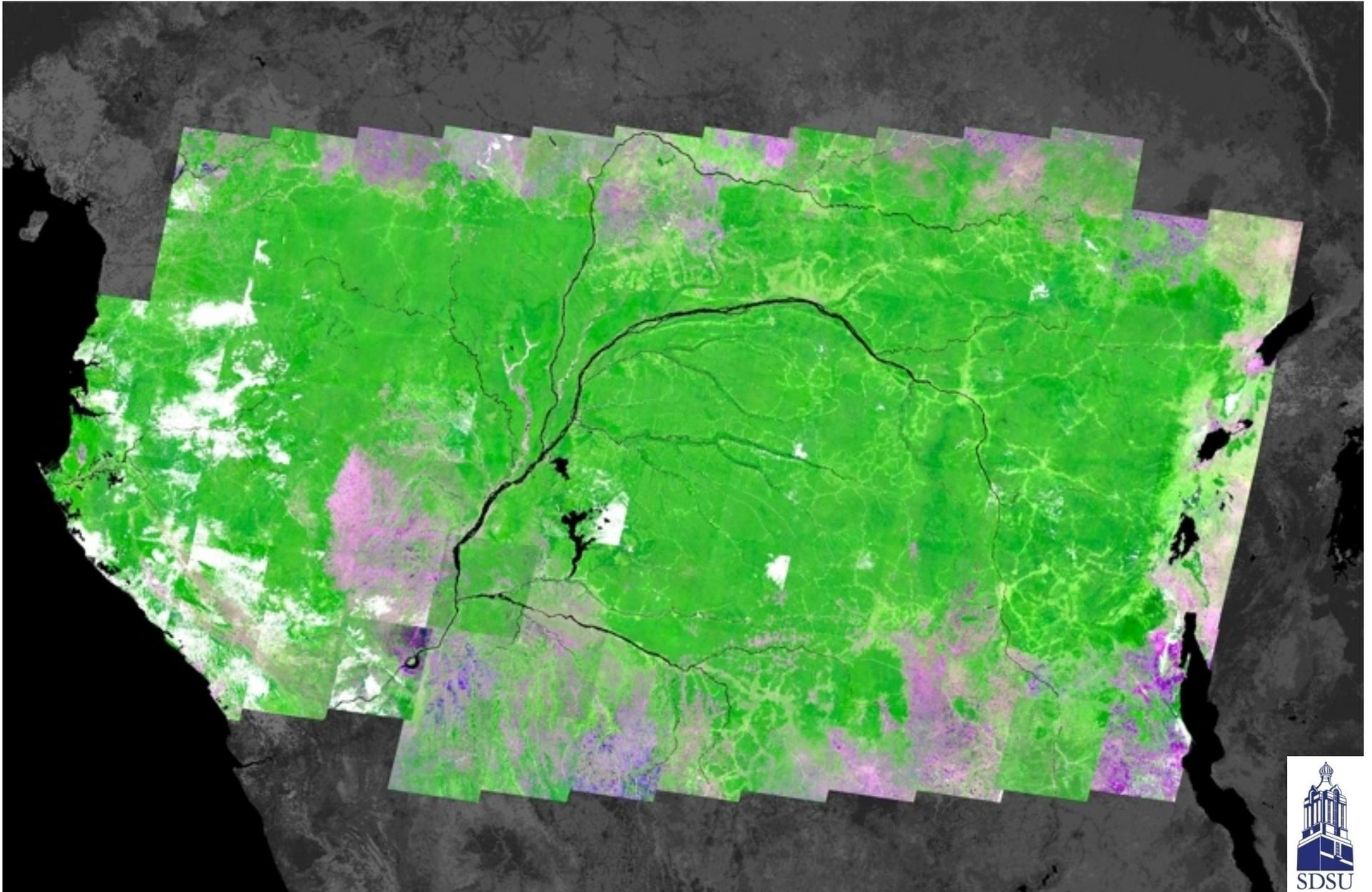
DOS-adjusted



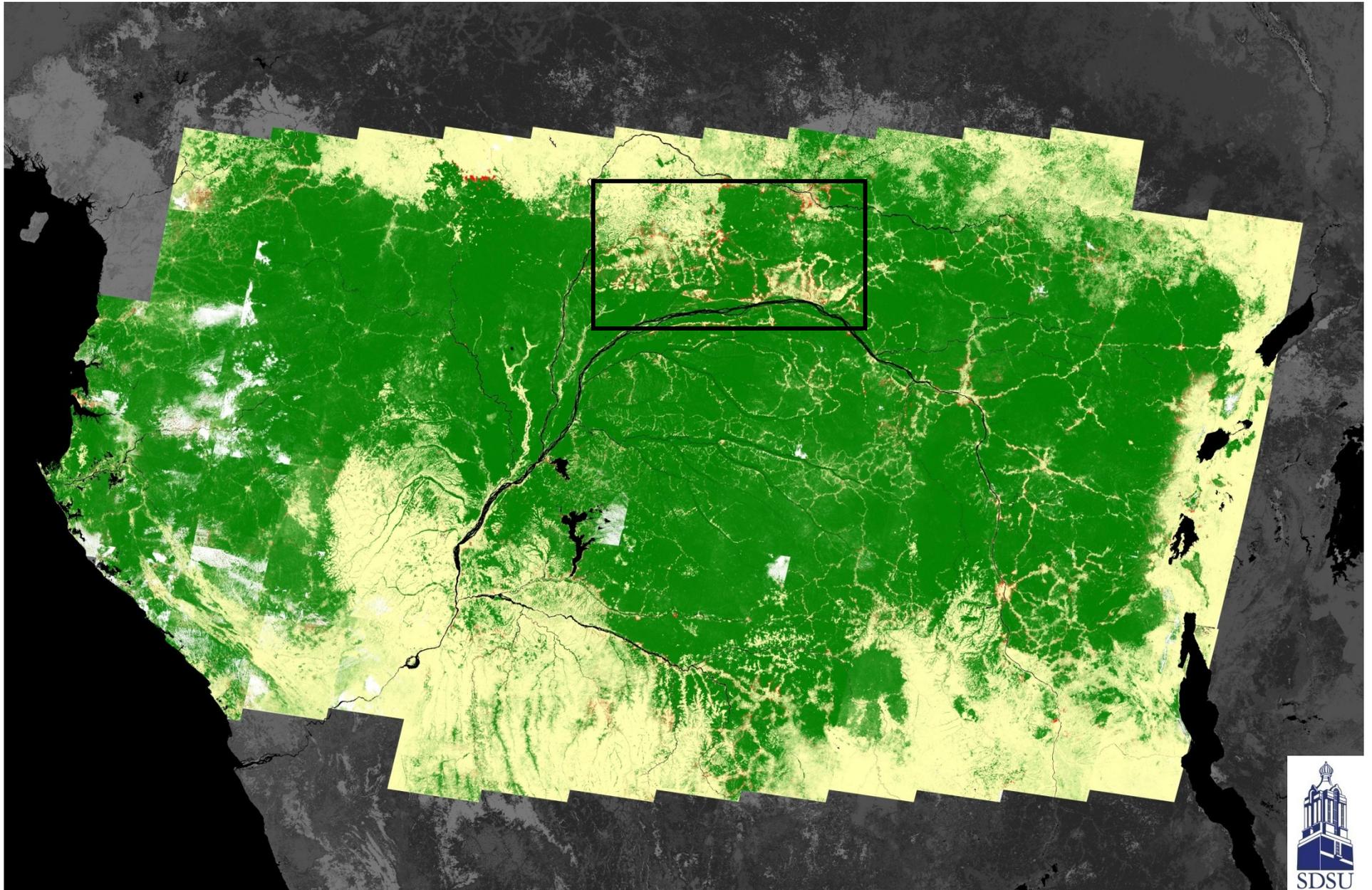
BRDF-adjusted



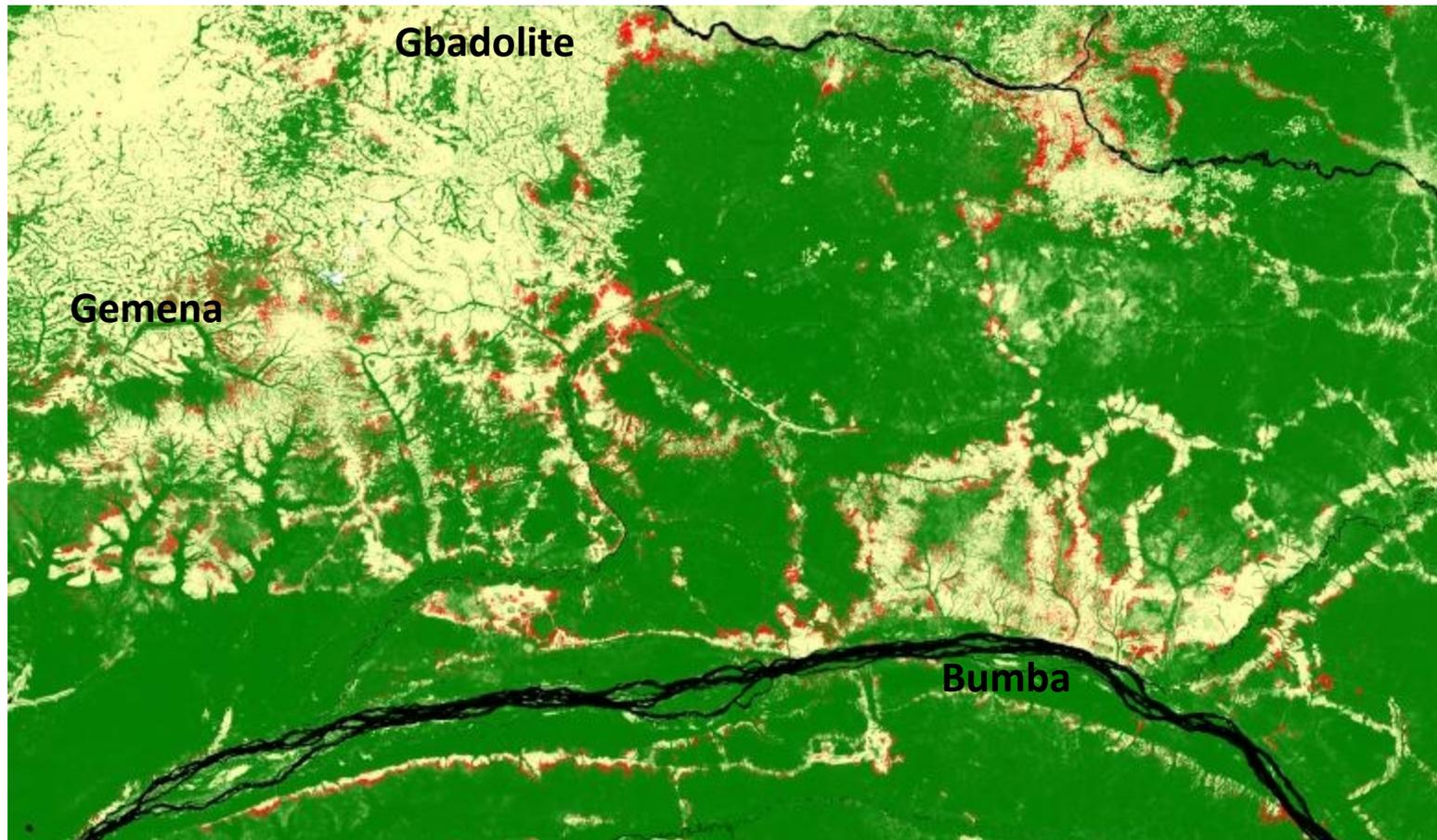
3-5 image inputs per path/row



Landsat forest cover and change



Full-resolution



Cameroon

**forest area= 197731.5 km²
forest area loss= 2207.6 km²
percentage = 1.10%**

Central African Republic

**forest area= 58090.4 km²
forest area loss= 1918.2 km²
percentage = 3.20%**

Equatorial Guinea

**forest area= 23702.4 km²
forest area loss= 274.9 km²
percentage = 1.15%**

Gabon

**forest area= 229318.4 km²
forest area loss= 2063.8 km²
percentage = 0.89%**

Republic of Congo

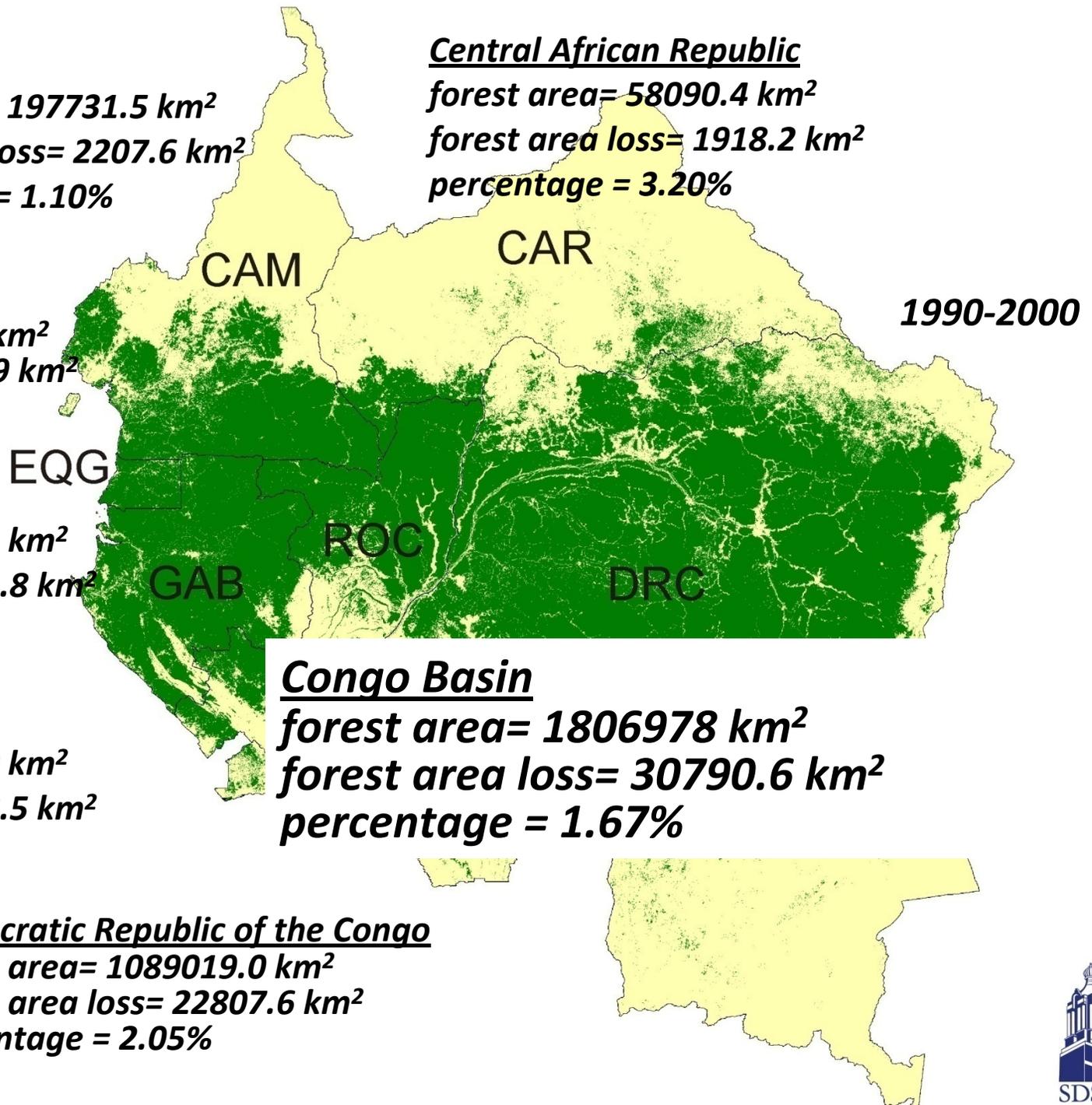
**forest area= 209116.0 km²
forest area loss= 1518.5 km²
percentage = 0.72%**

Democratic Republic of the Congo

**forest area= 1089019.0 km²
forest area loss= 22807.6 km²
percentage = 2.05%**

Congo Basin

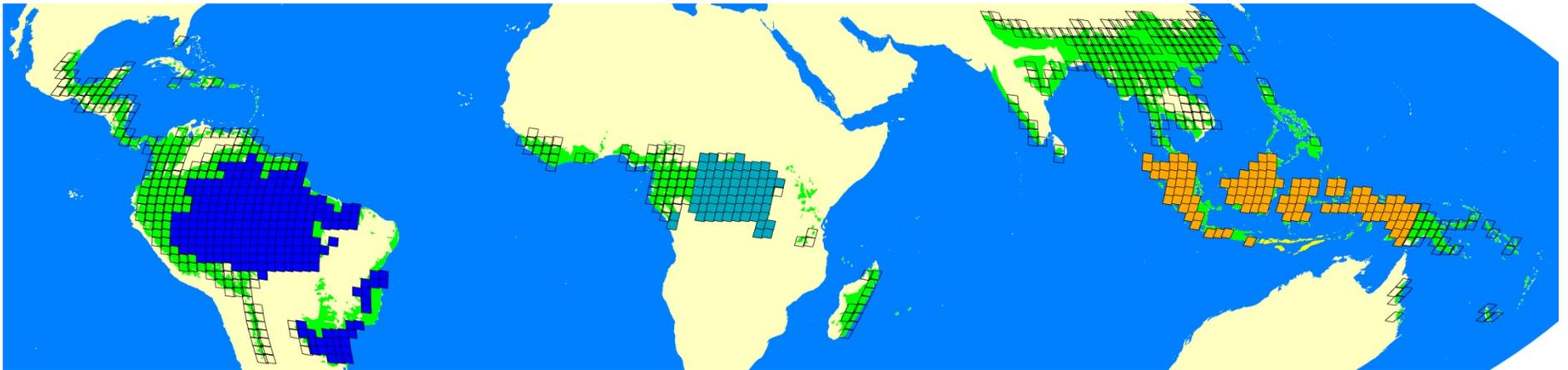
**forest area= 1806978 km²
forest area loss= 30790.6 km²
percentage = 1.67%**



Different approaches

- 1) Epochal composites
 - Combine best observations over a given interval to create cloud-free image
 - Cloud-free composites require such a long compositing period that change occurs within the composite interval
- 2) Time-series characterizations
 - Map each good pixel and create time-series of forest cover estimates in metric space
 - No image composite needed
 - Unequal numbers of cover estimates over the regions (scene overlaps, SLC-off gaps)

Pan-tropical forest cover and change with Landsat data



- How to use the entire ETM+ archive to produce per pixel forest cover and change?
- Start using all images with ACCA cloud cover less than 50%

2000-2

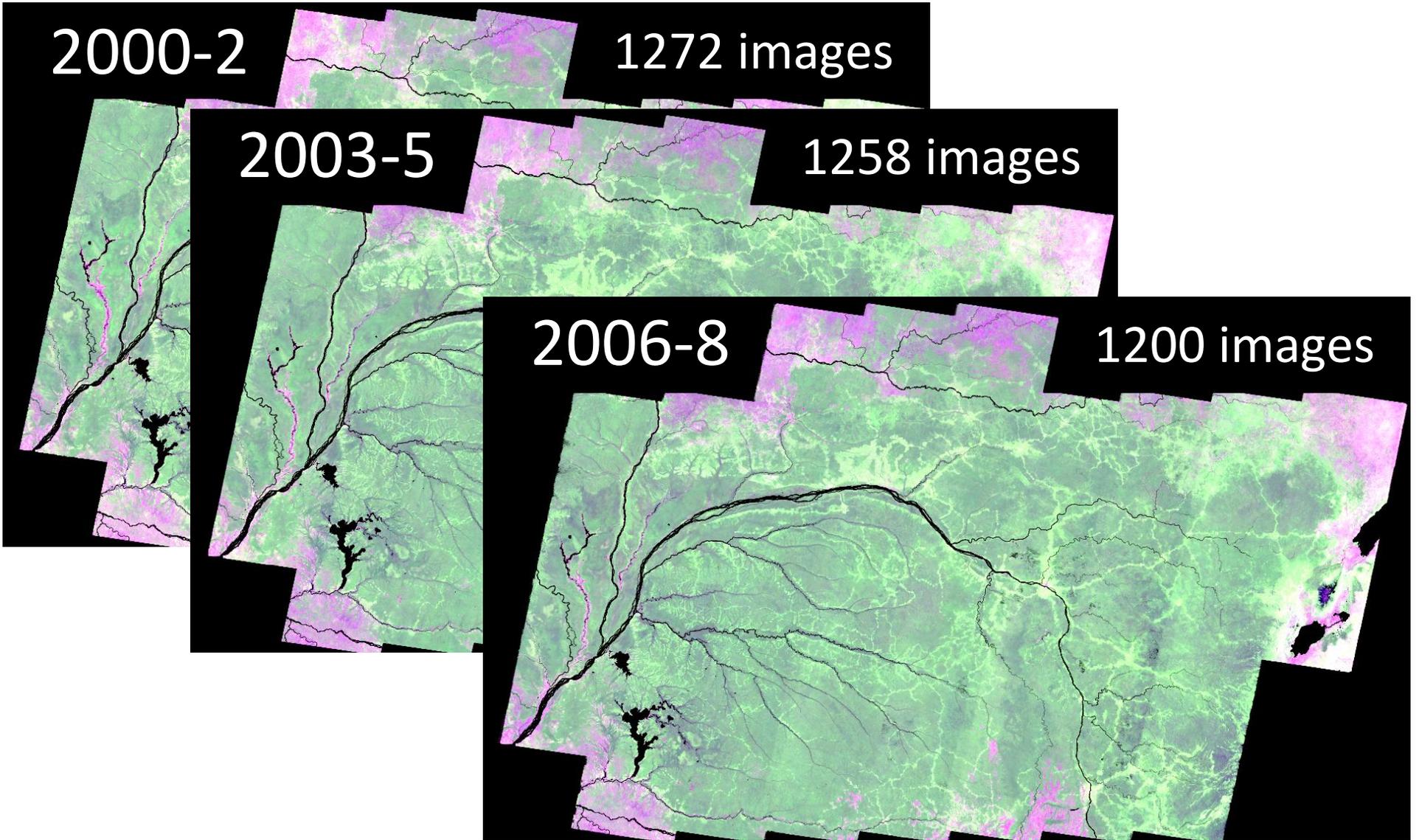
1272 images

2003-5

1258 images

2006-8

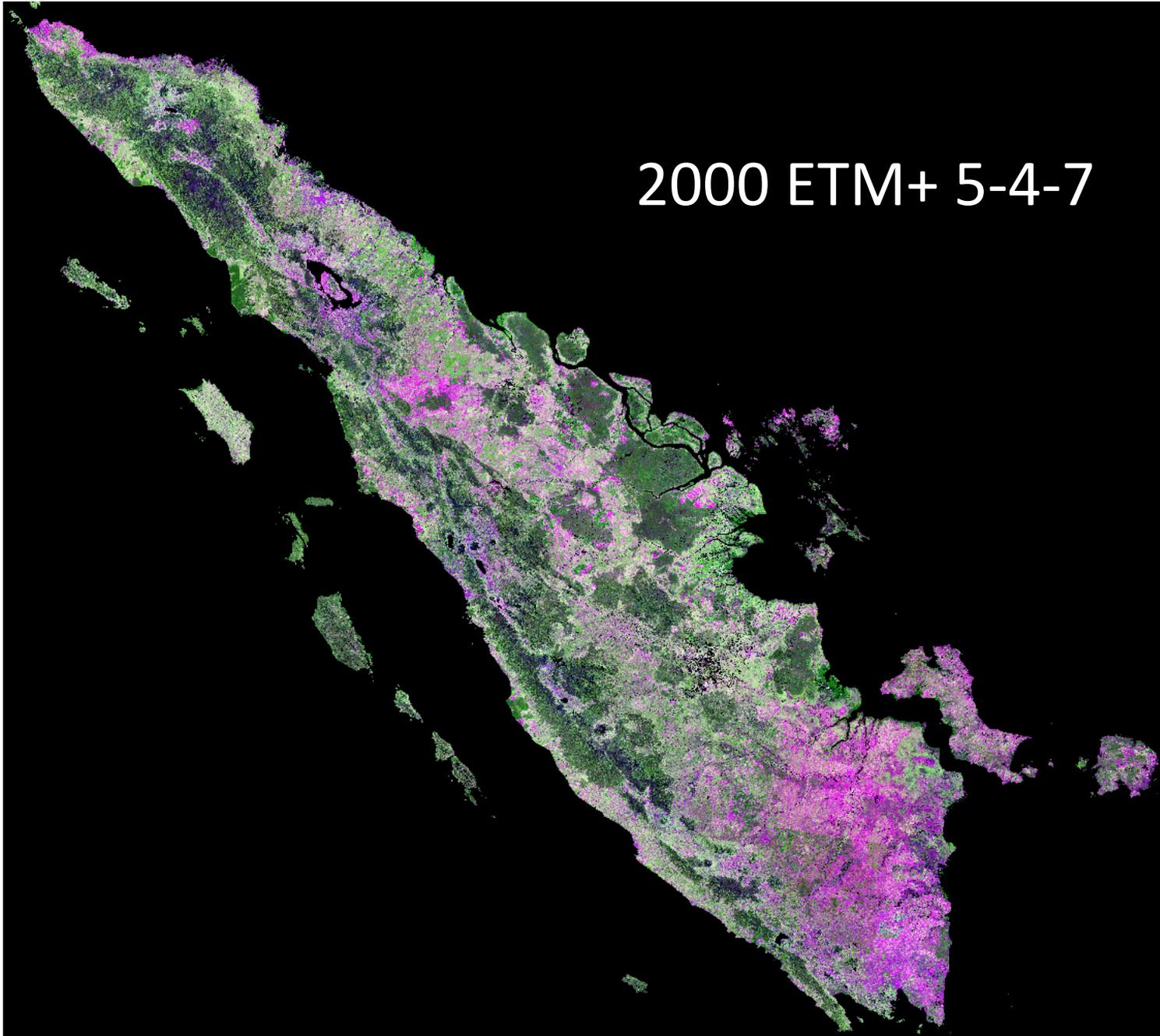
1200 images



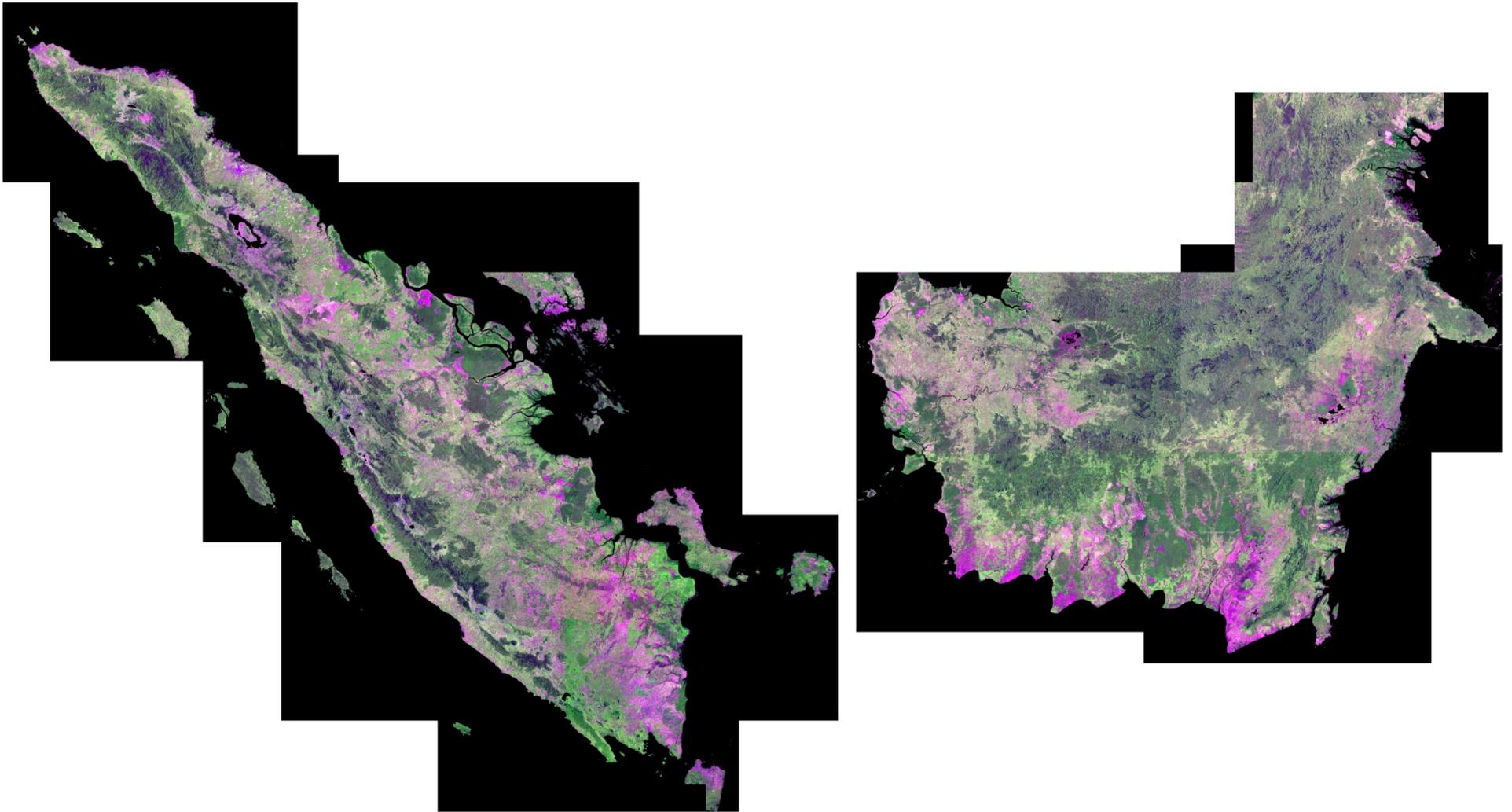


Google imagery for Sumatra

2000 ETM+ 5-4-7

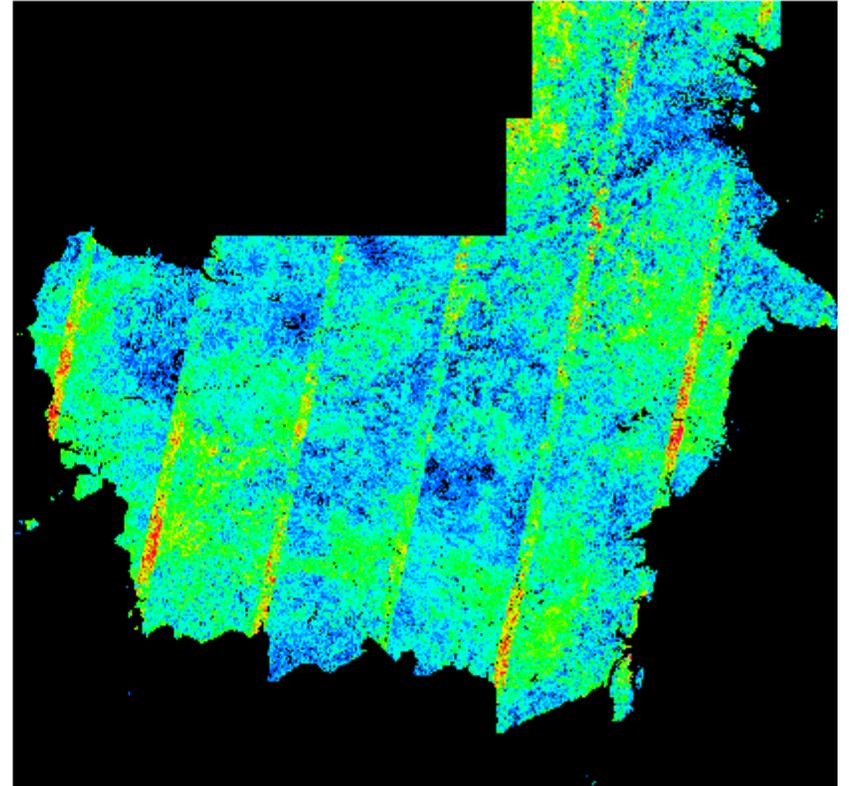
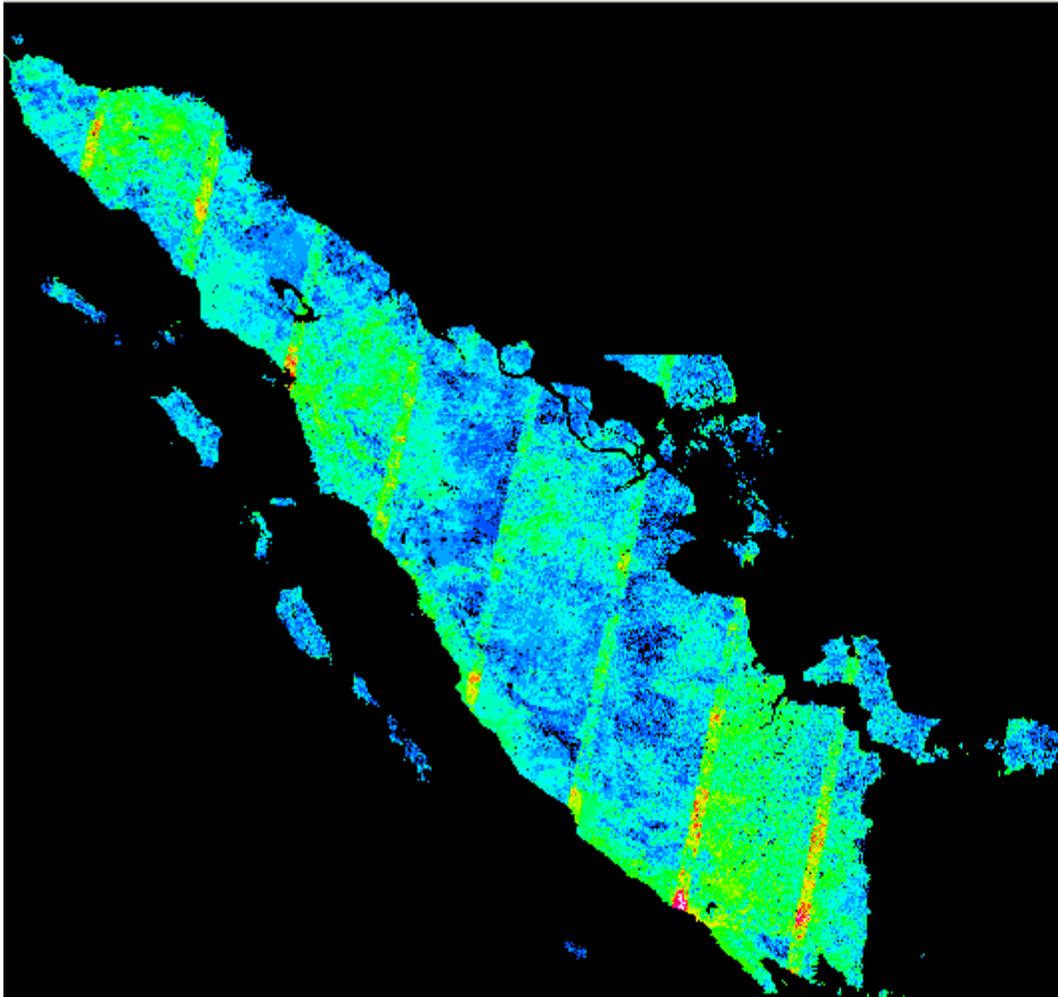


Indonesia, 1999 to 2009

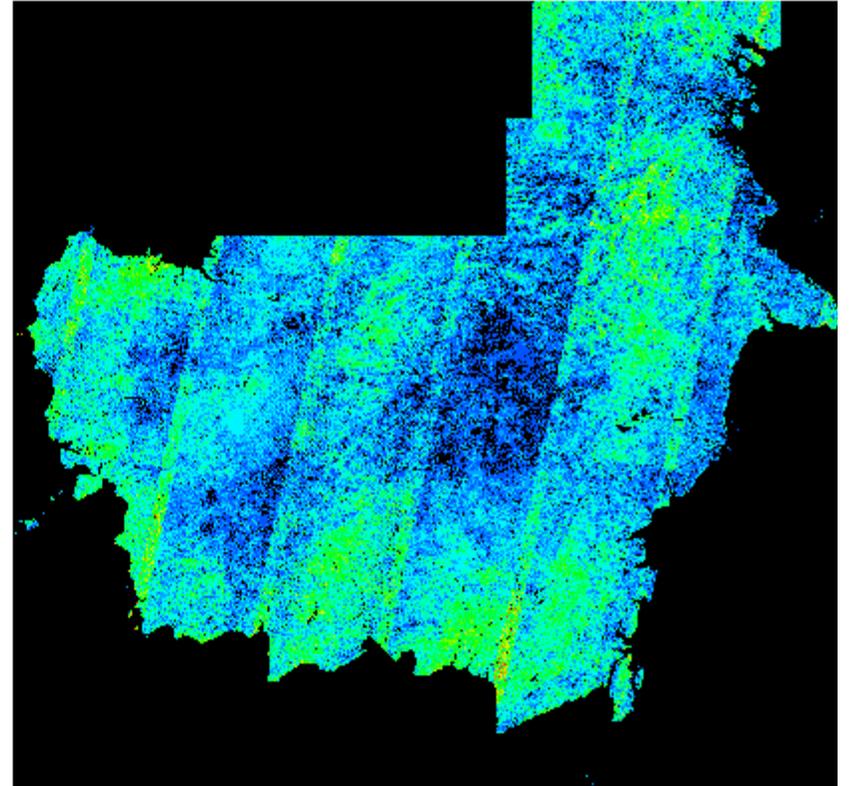
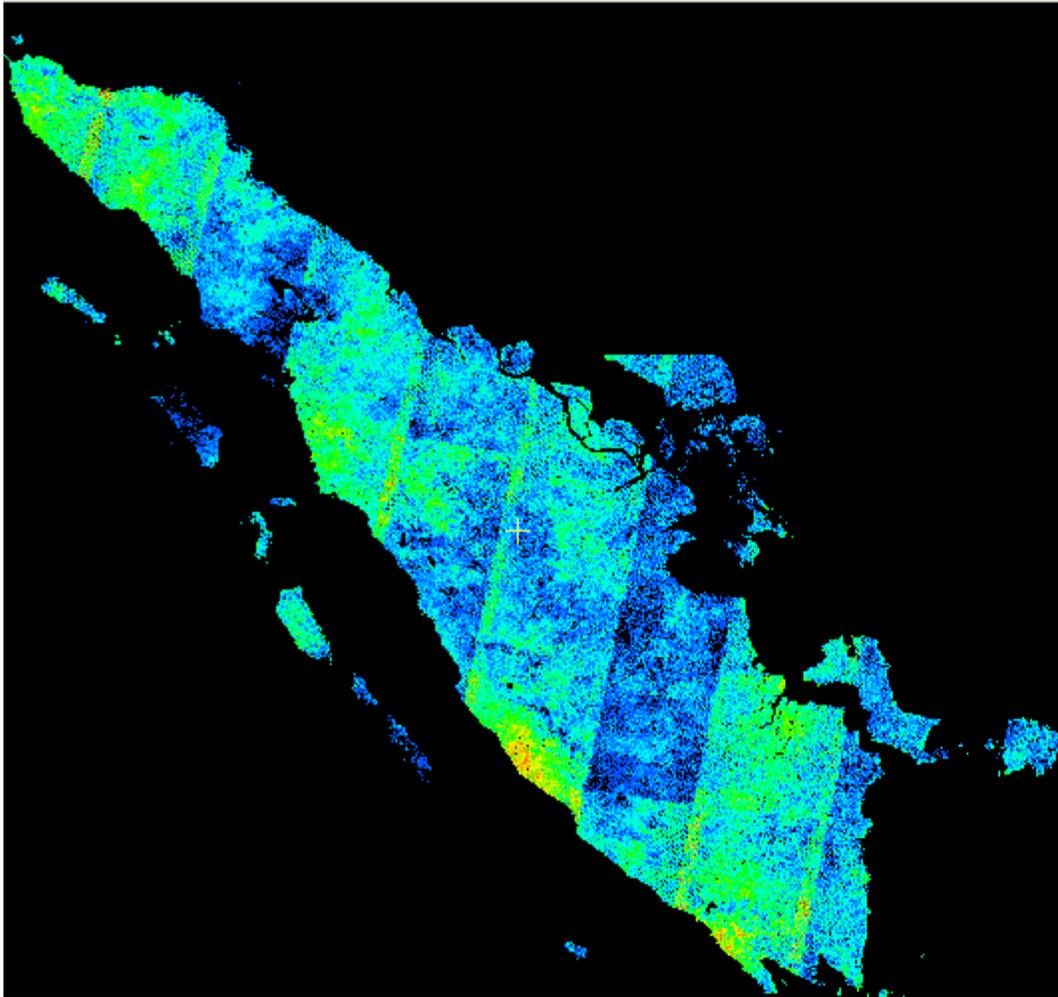


6189 images

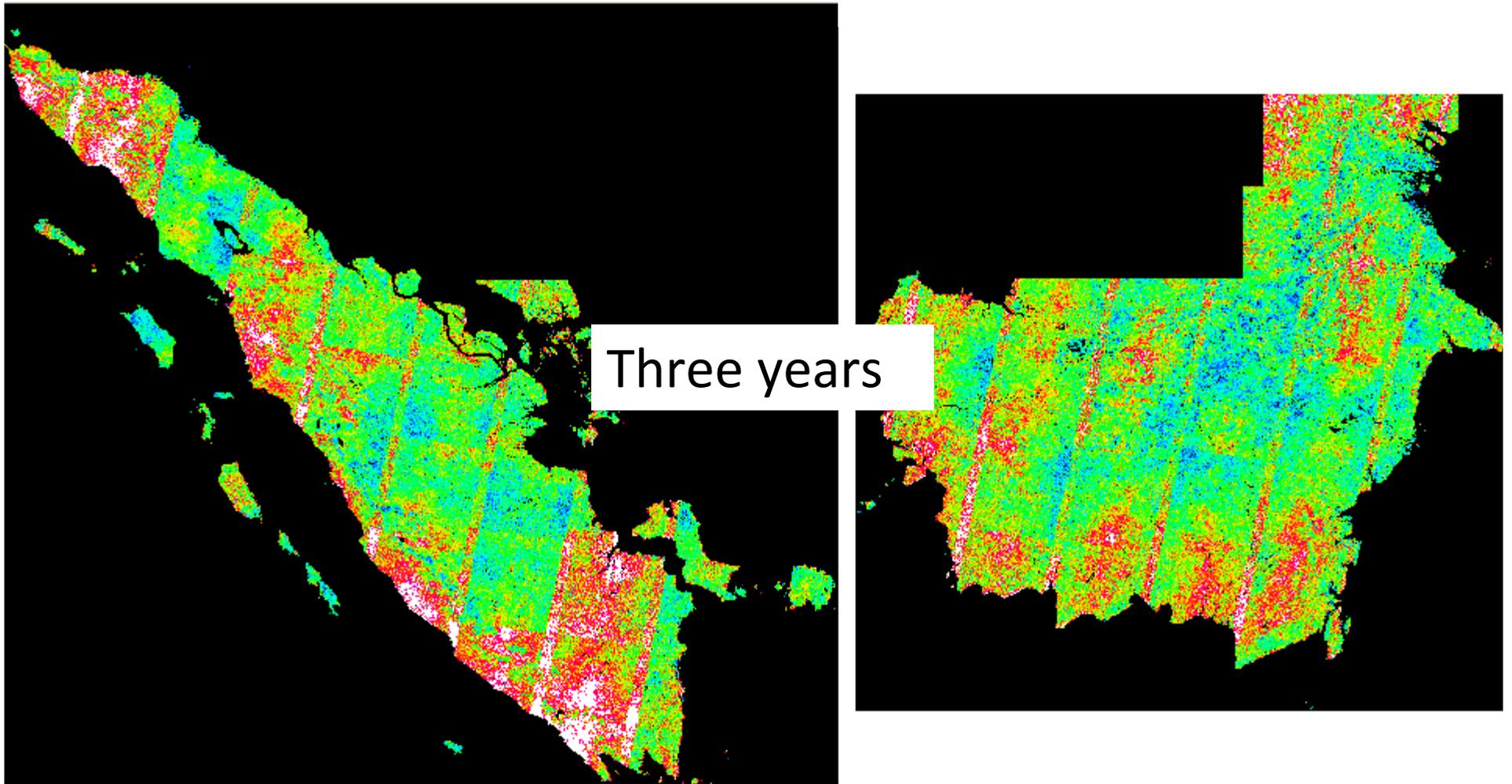
Number of good observations in 2002 composite (a full SLC-on year)



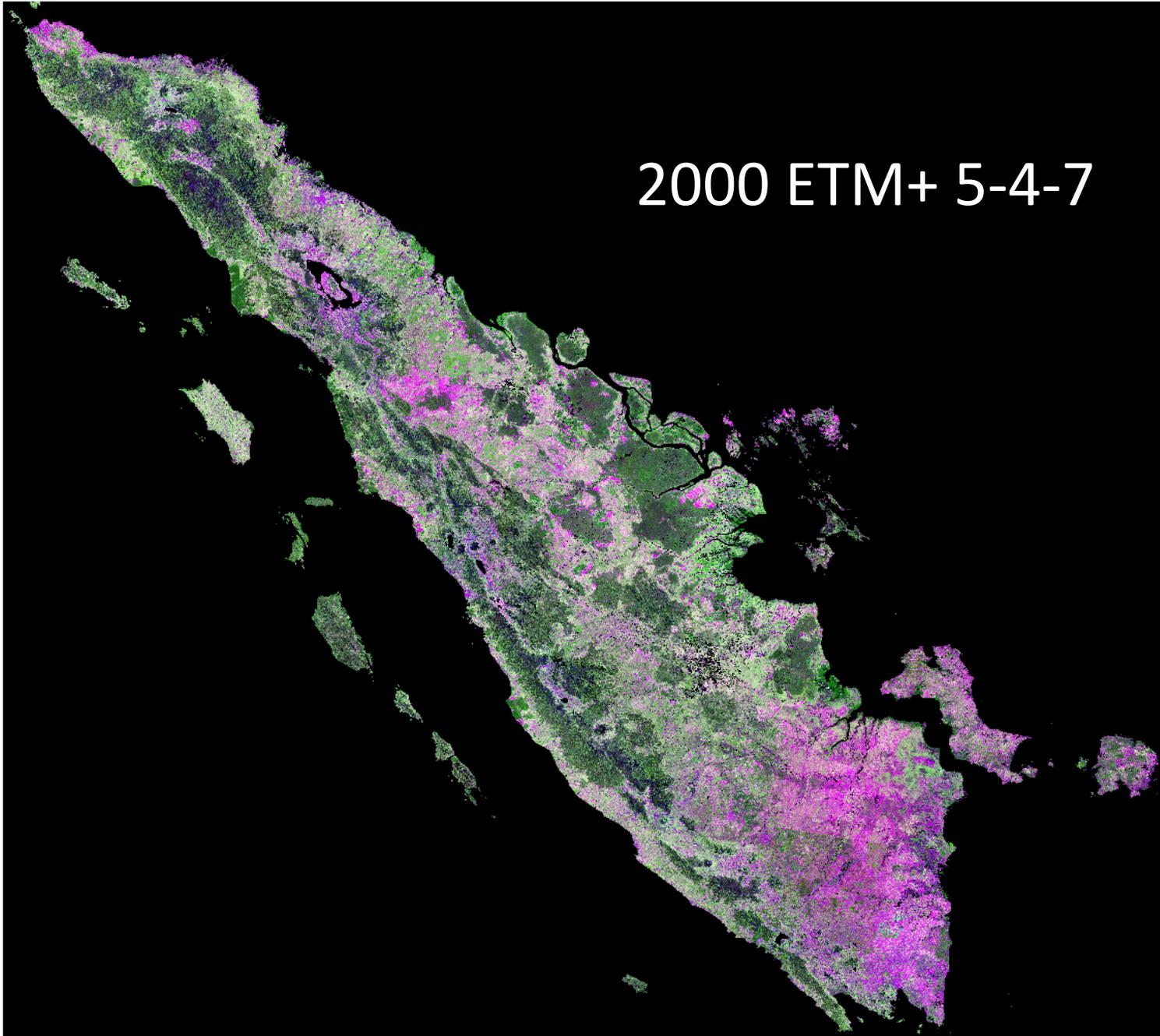
Number of good observations in 2004 composite (a full SLC-off year)



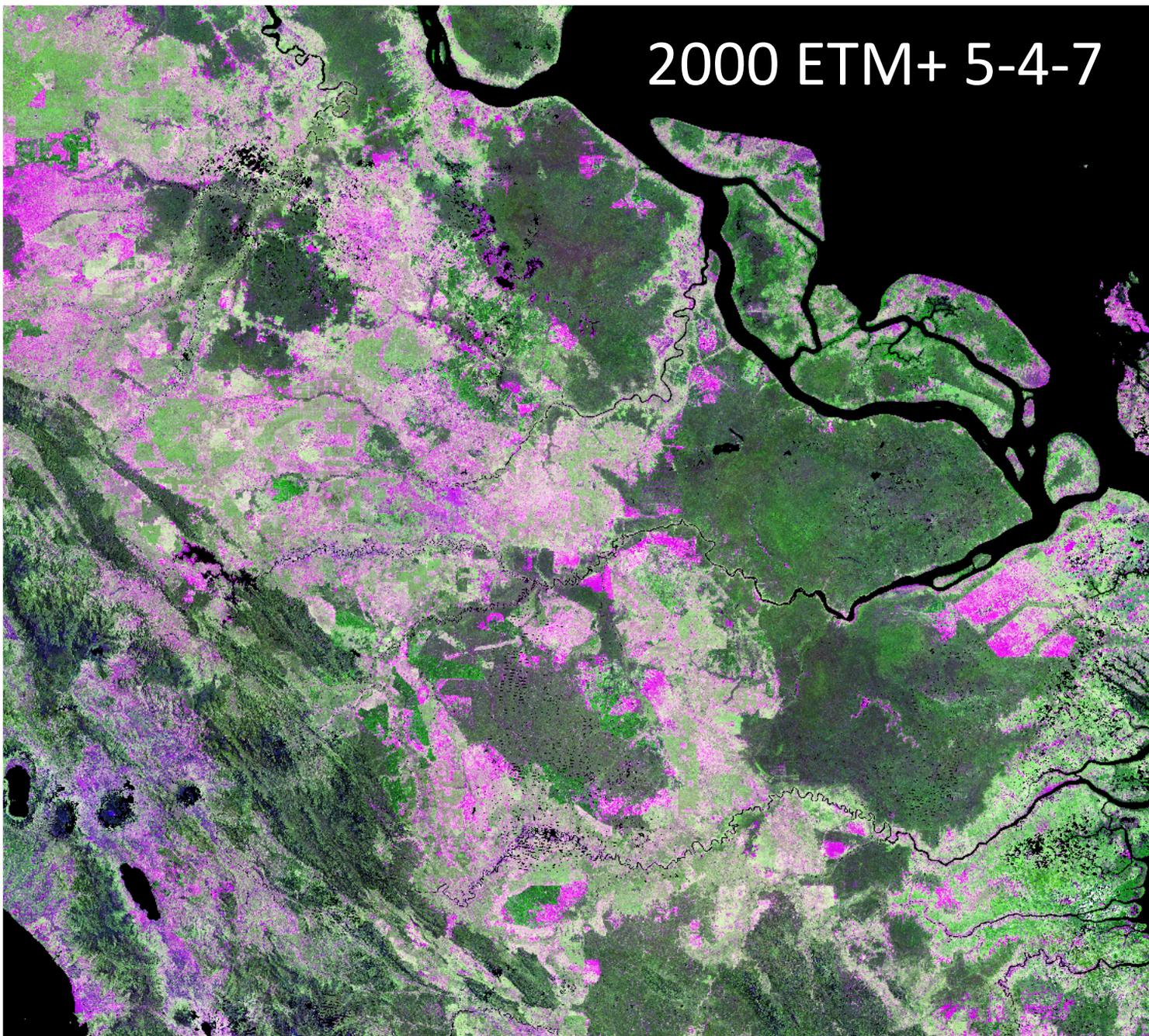
Number of good observations in 2004-2006 composite (full SLC-off years)

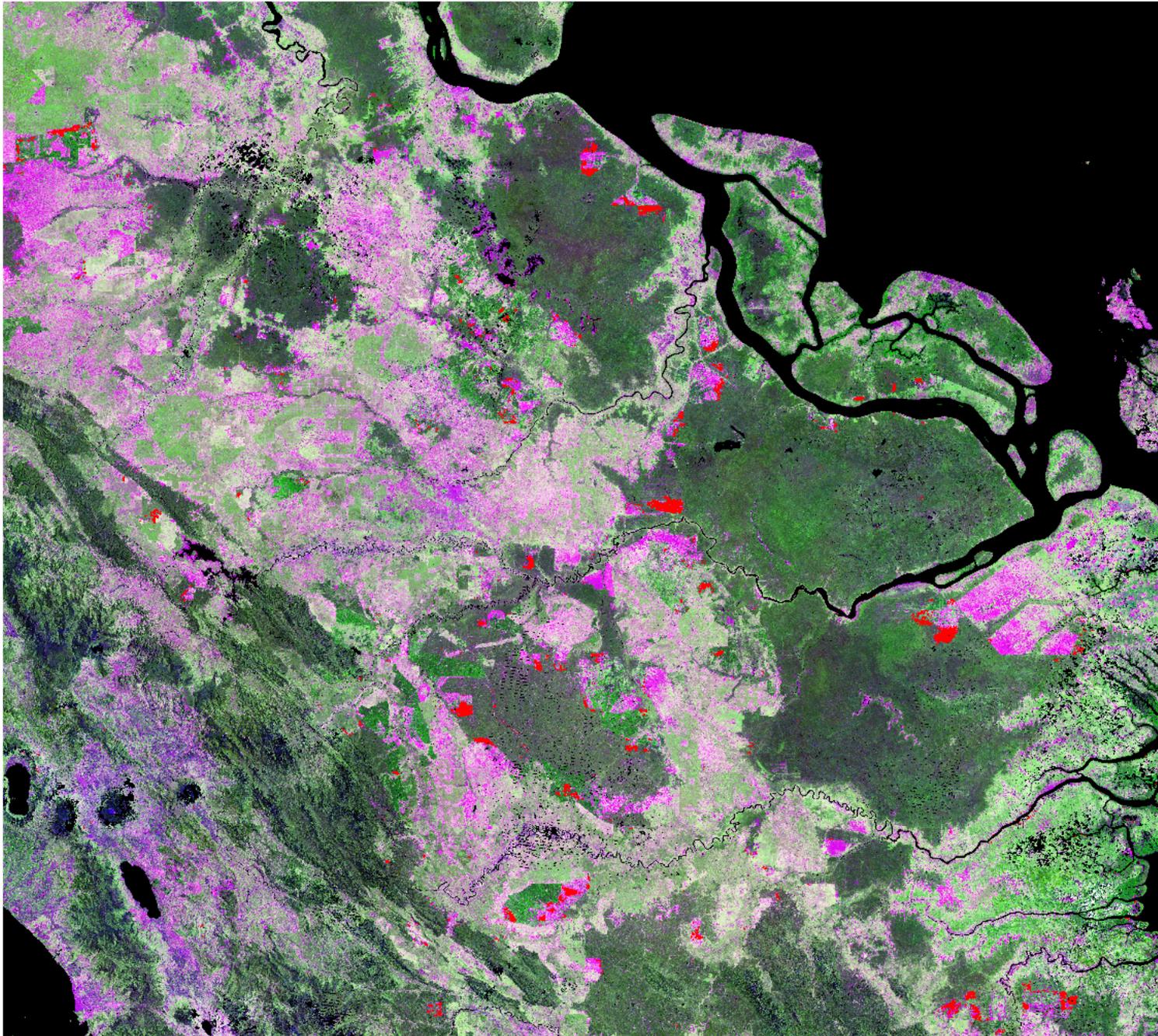


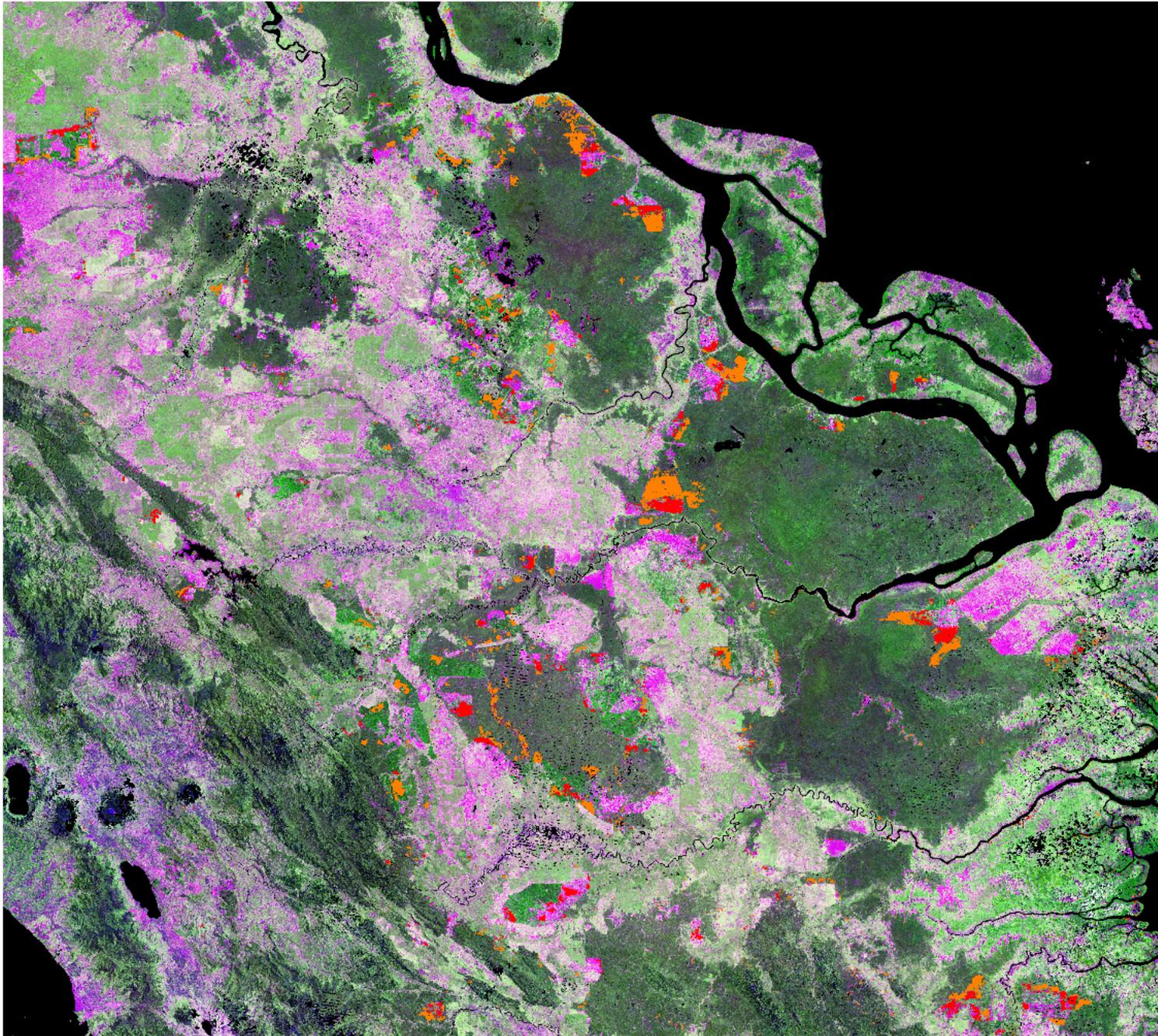
2000 ETM+ 5-4-7

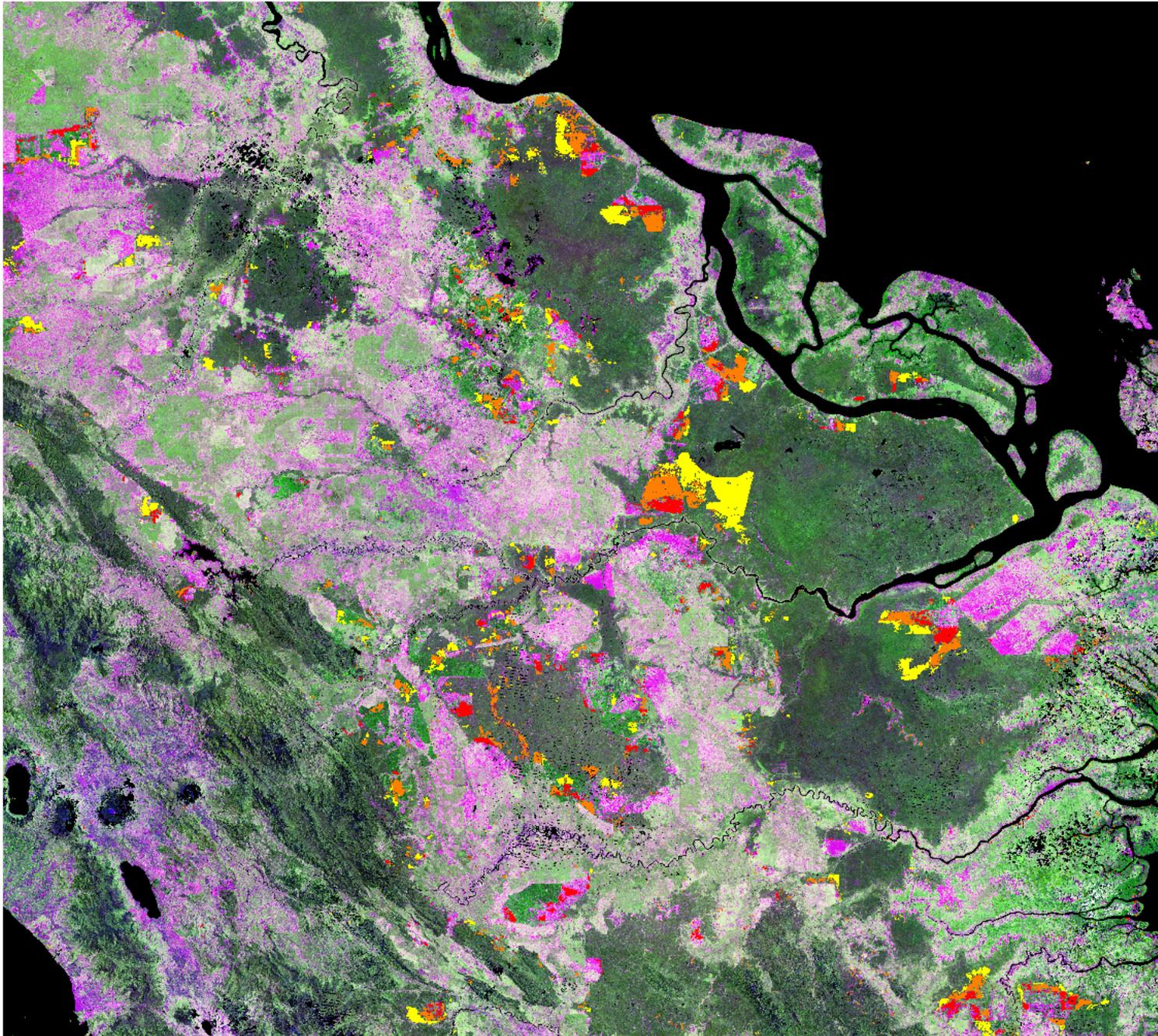


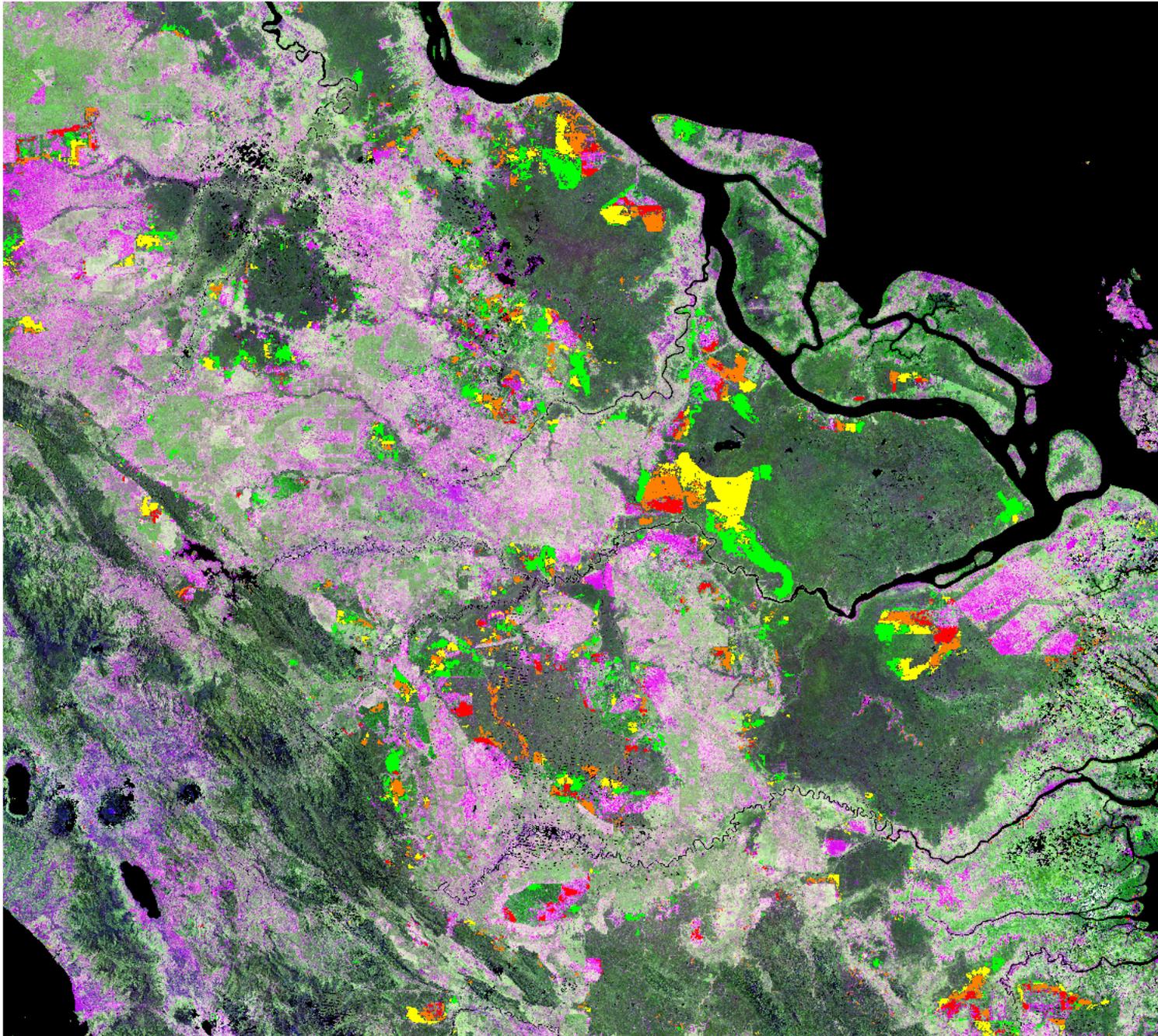
2000 ETM+ 5-4-7

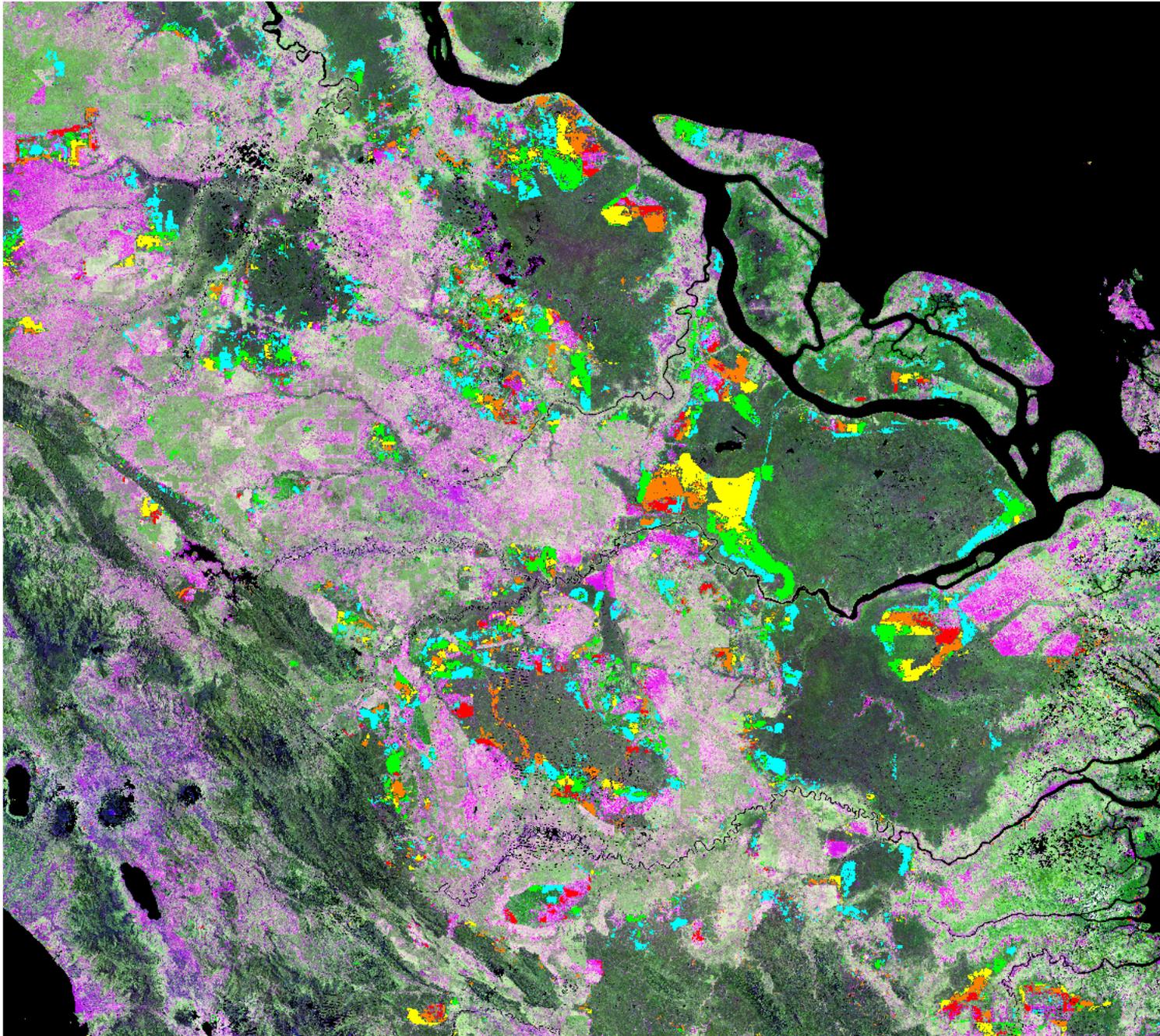


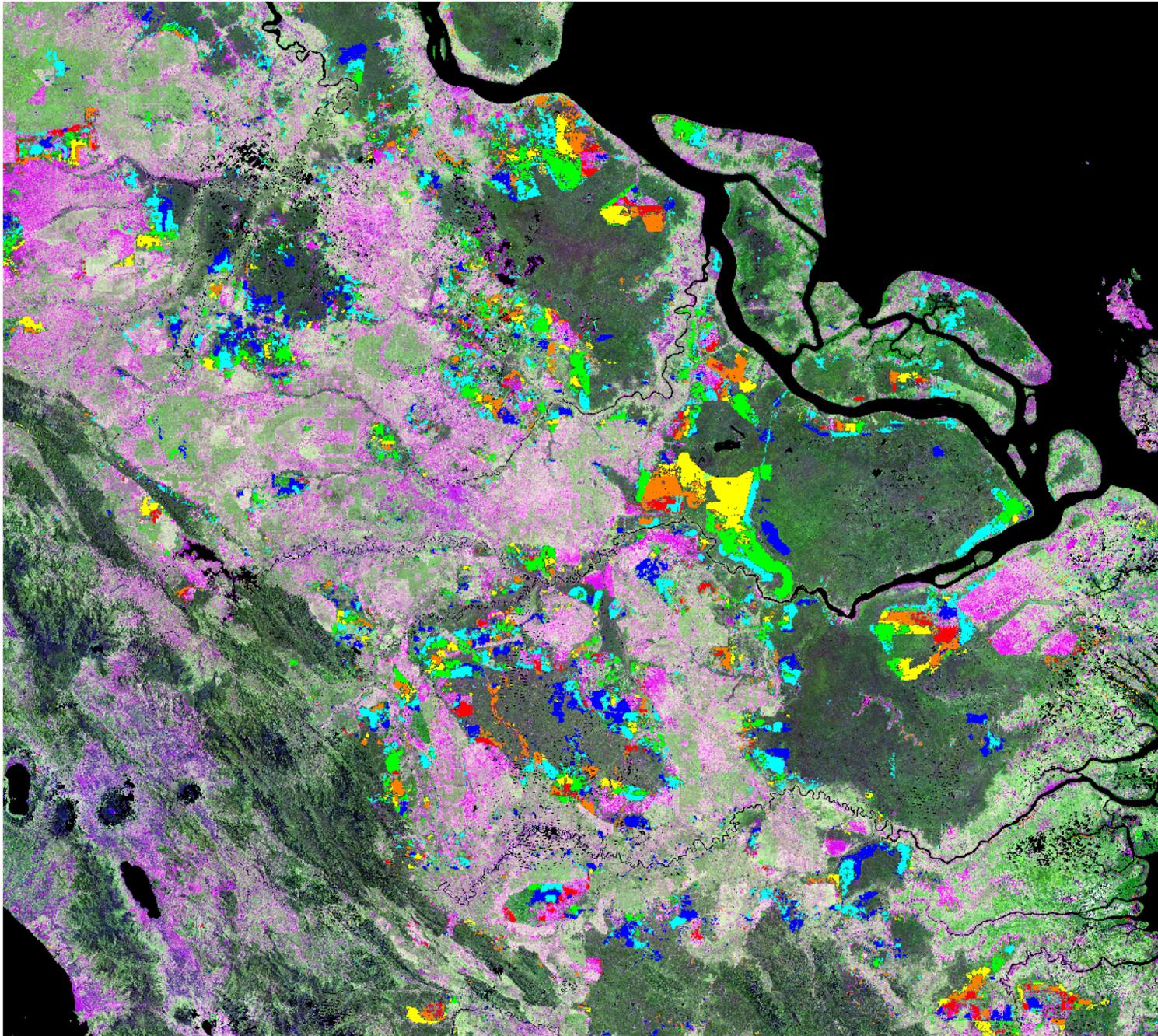


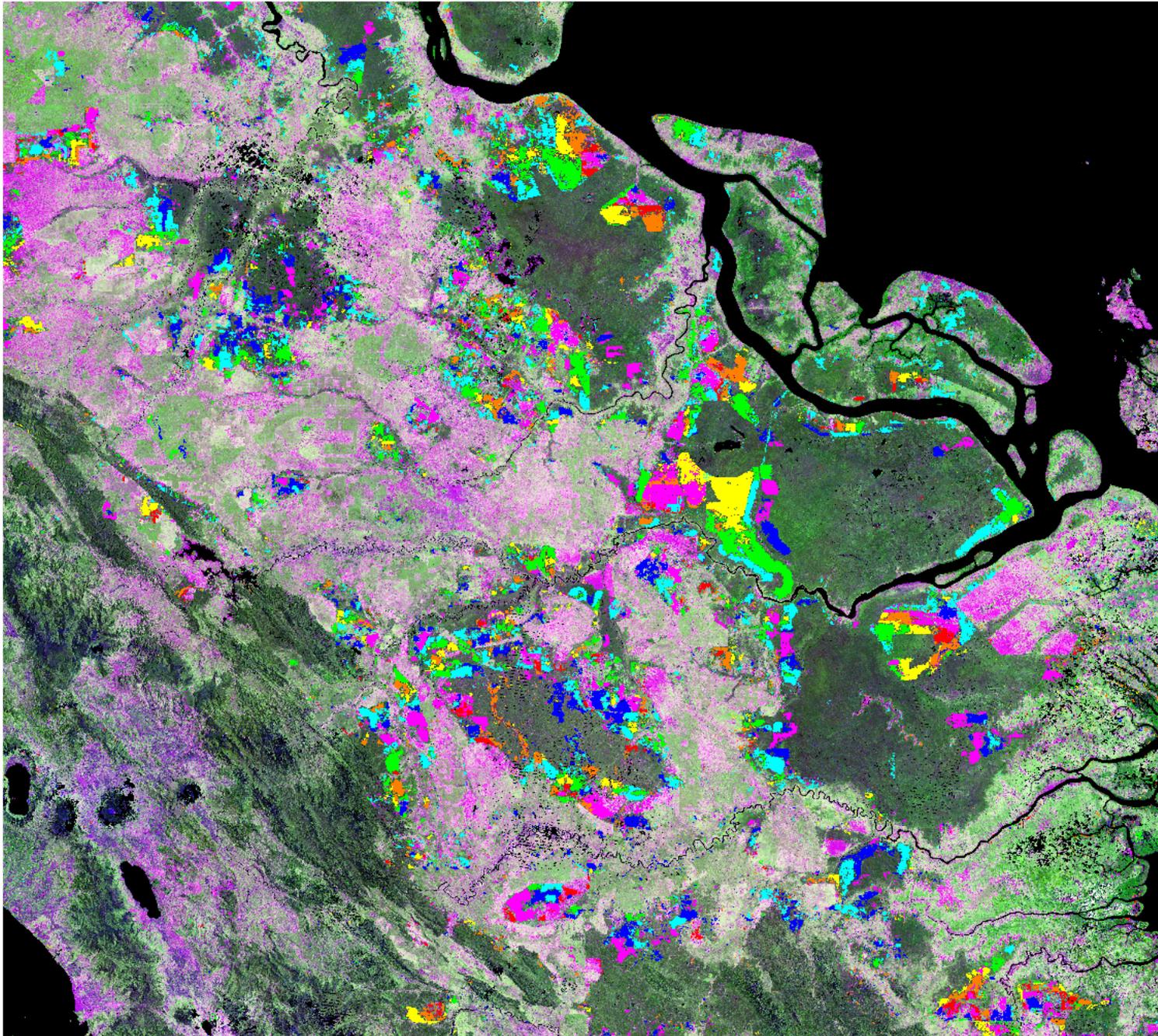




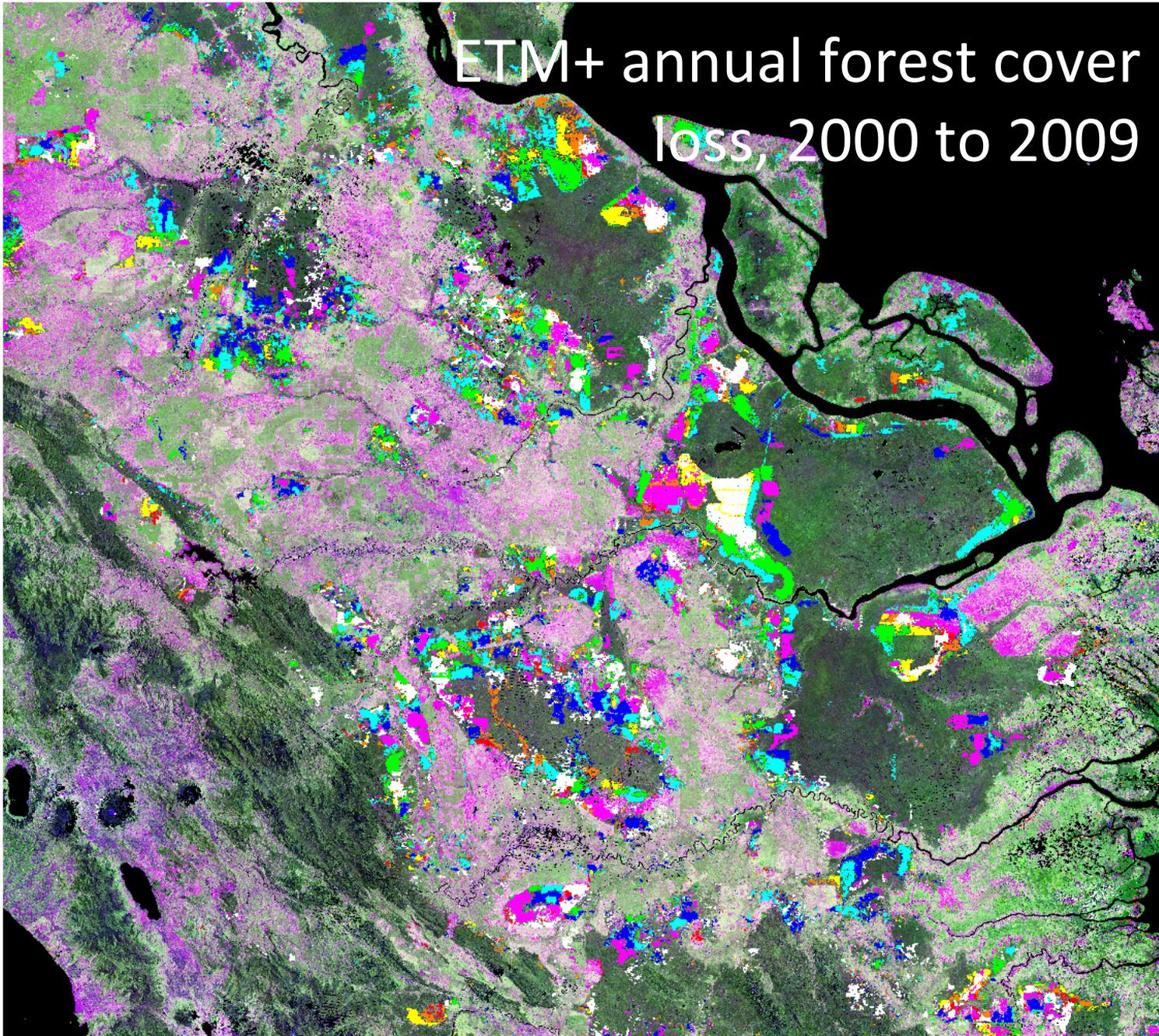




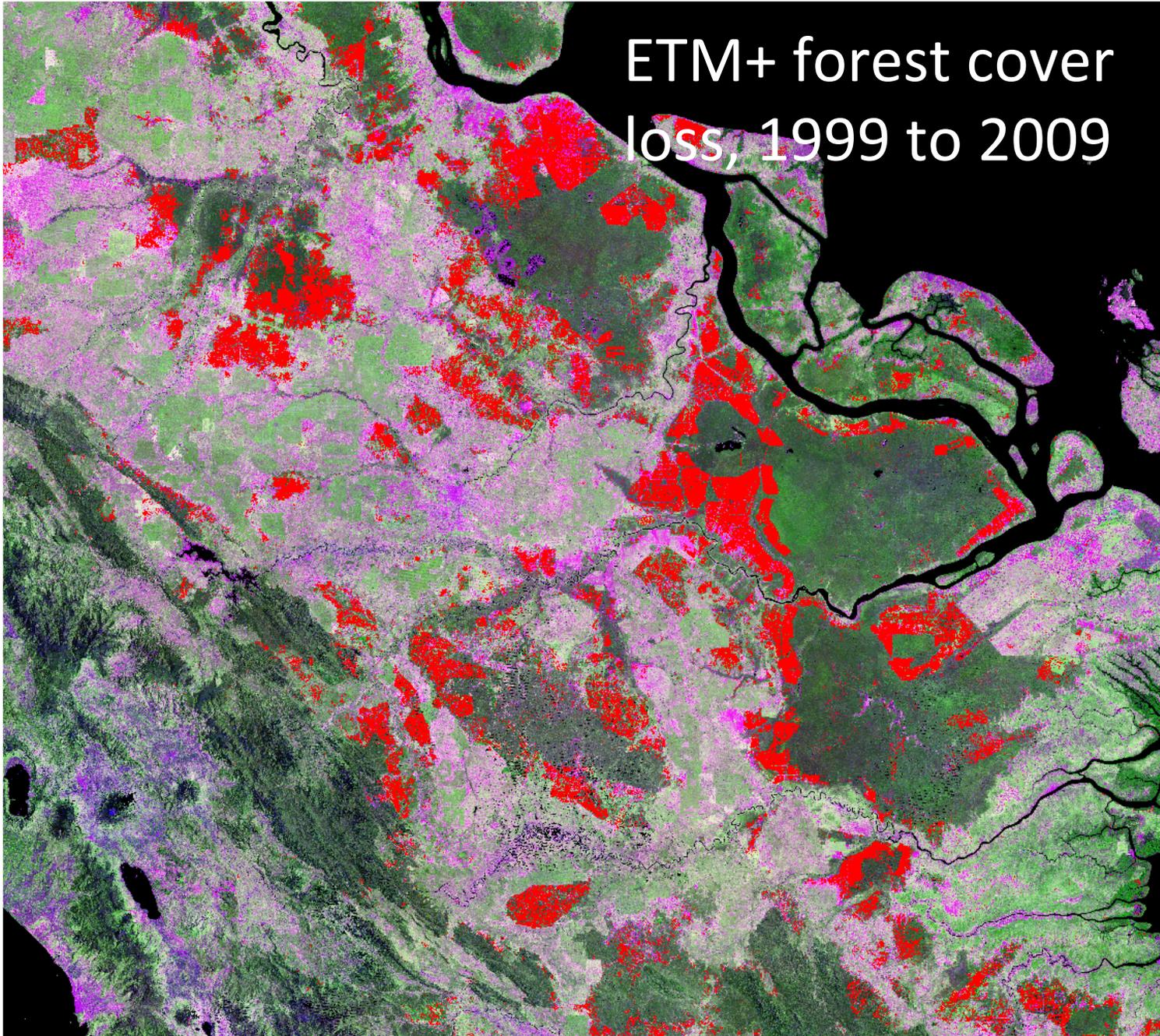




ETM+ annual forest cover loss, 2000 to 2009

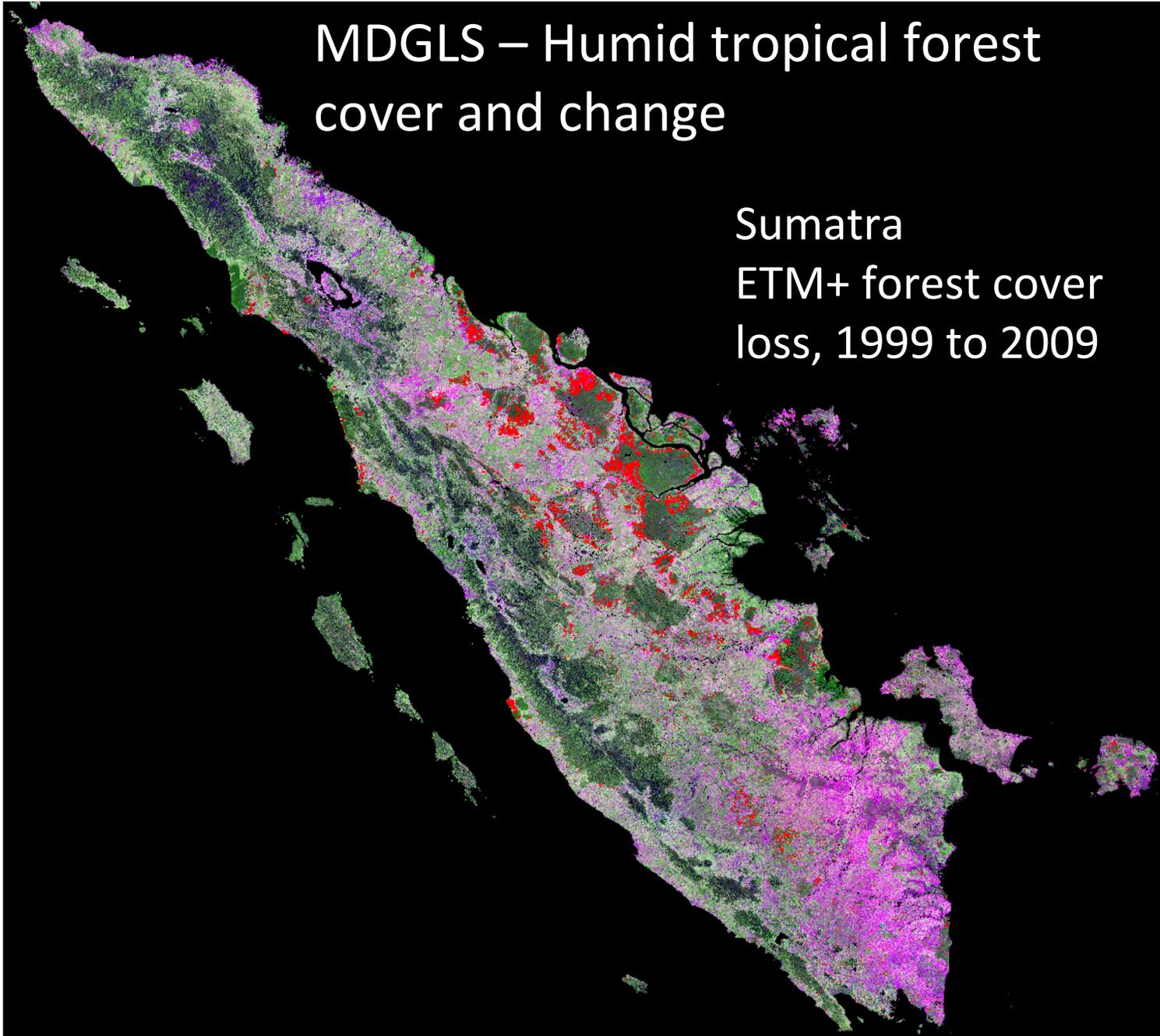


ETM+ forest cover loss, 1999 to 2009

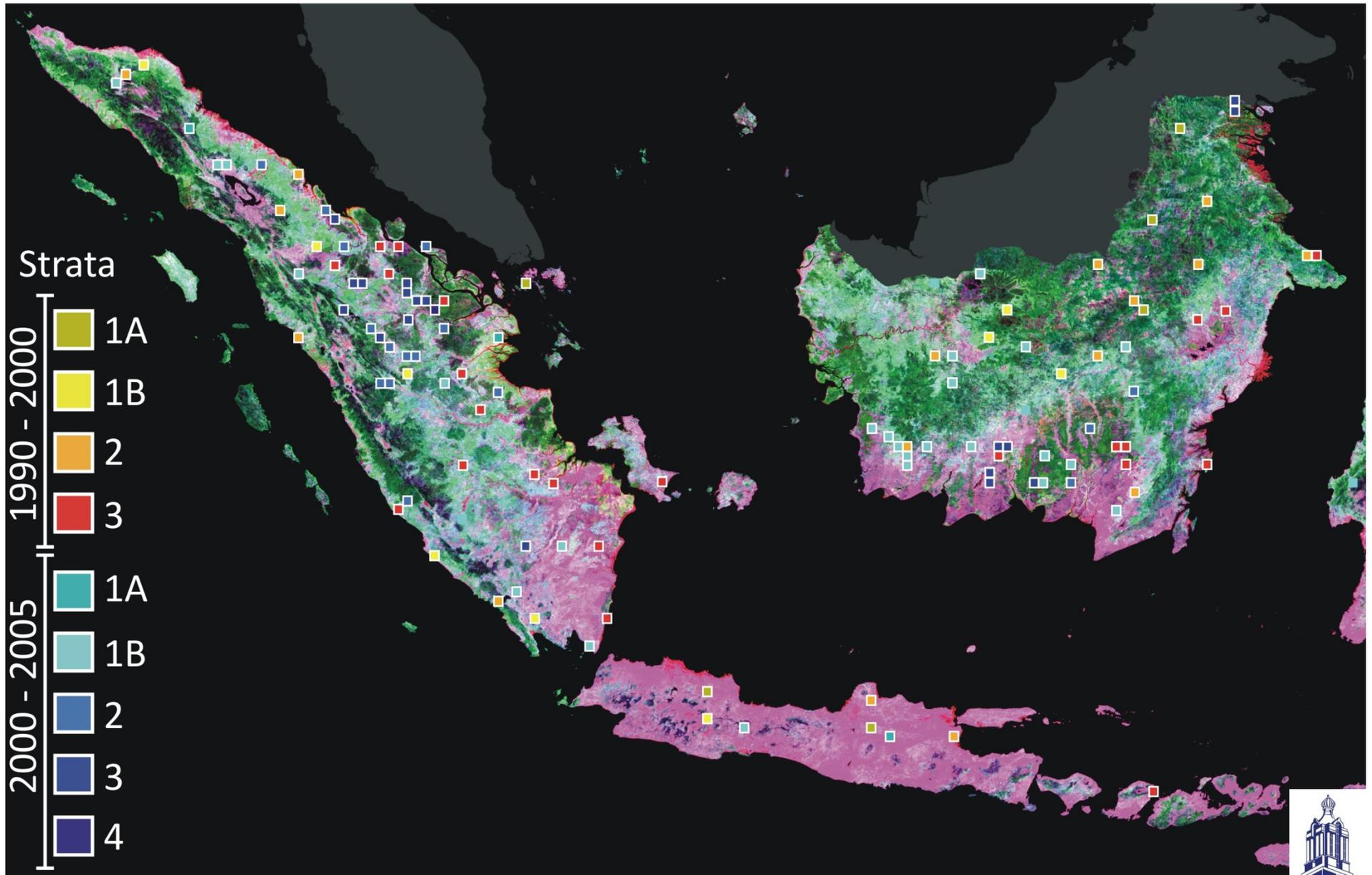


MDGLS – Humid tropical forest cover and change

Sumatra
ETM+ forest cover
loss, 1999 to 2009

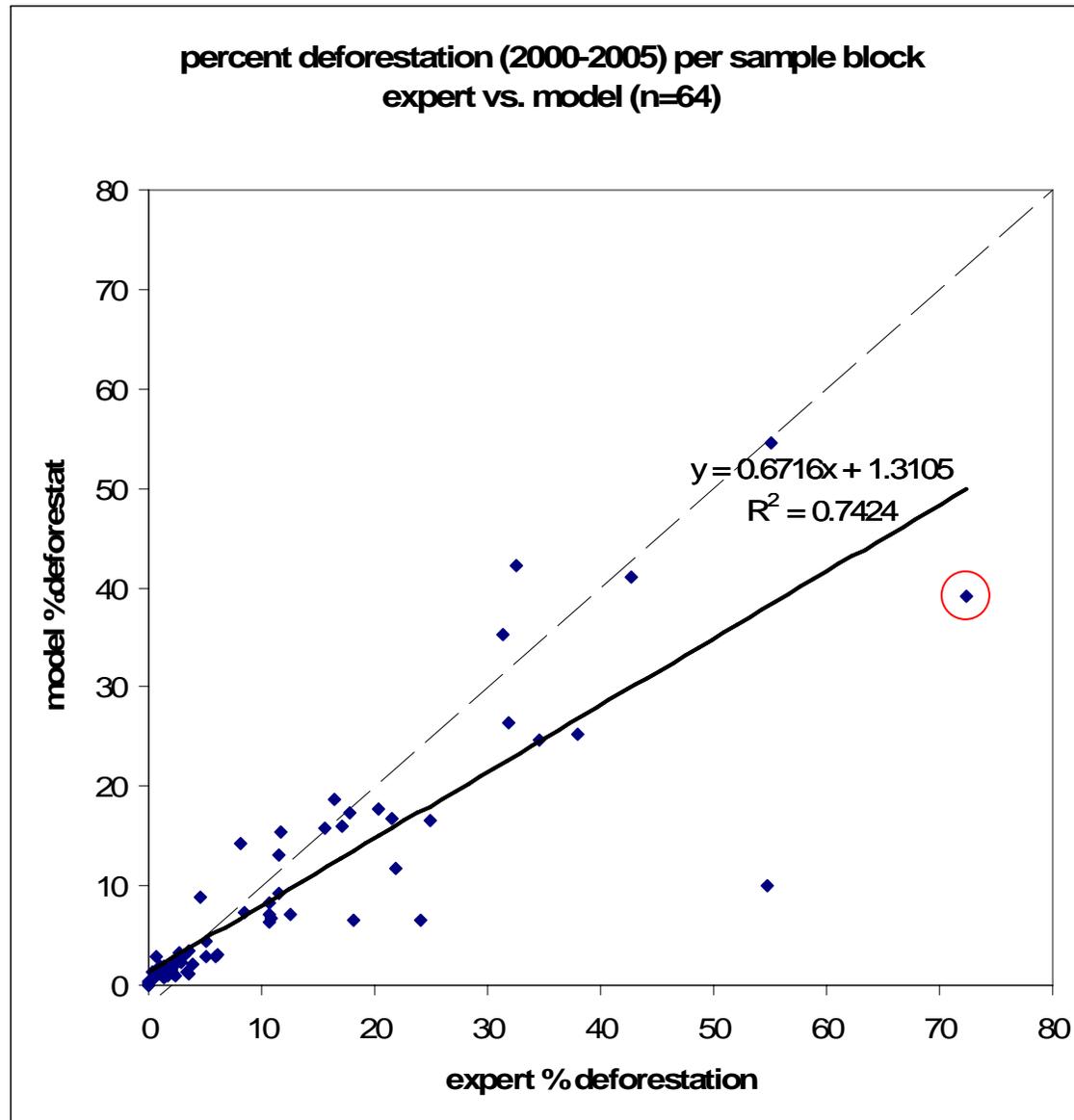


ETM+ forest cover loss, 1999 to 2009



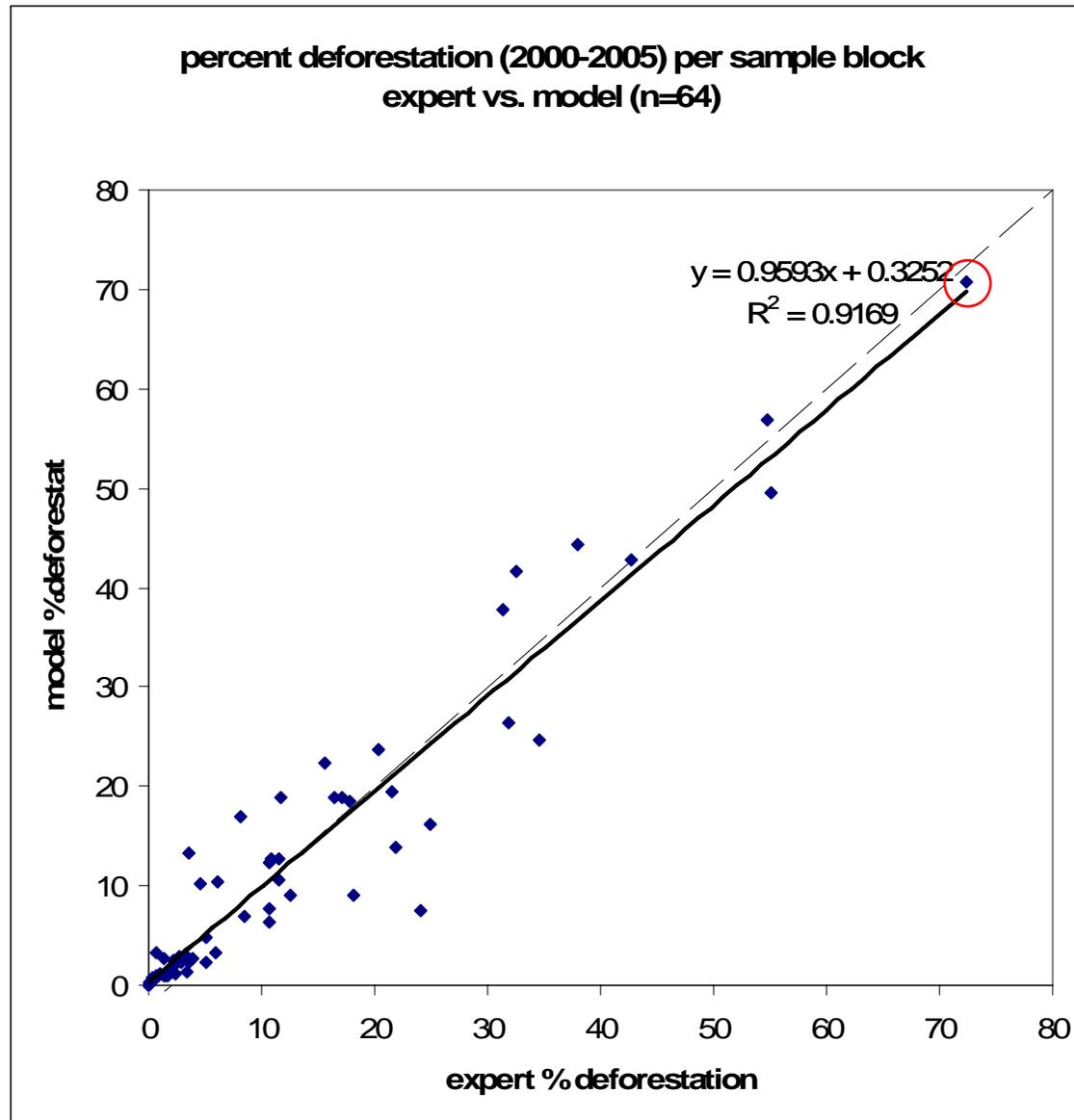
Comparison of model (map) results with expert- interpreted sample blocks I

Model based on differencing the time 1 / time 2 characterizations



Comparison of model (map) results with expert- interpreted sample blocks II

Model based on full time series analysis per pixel



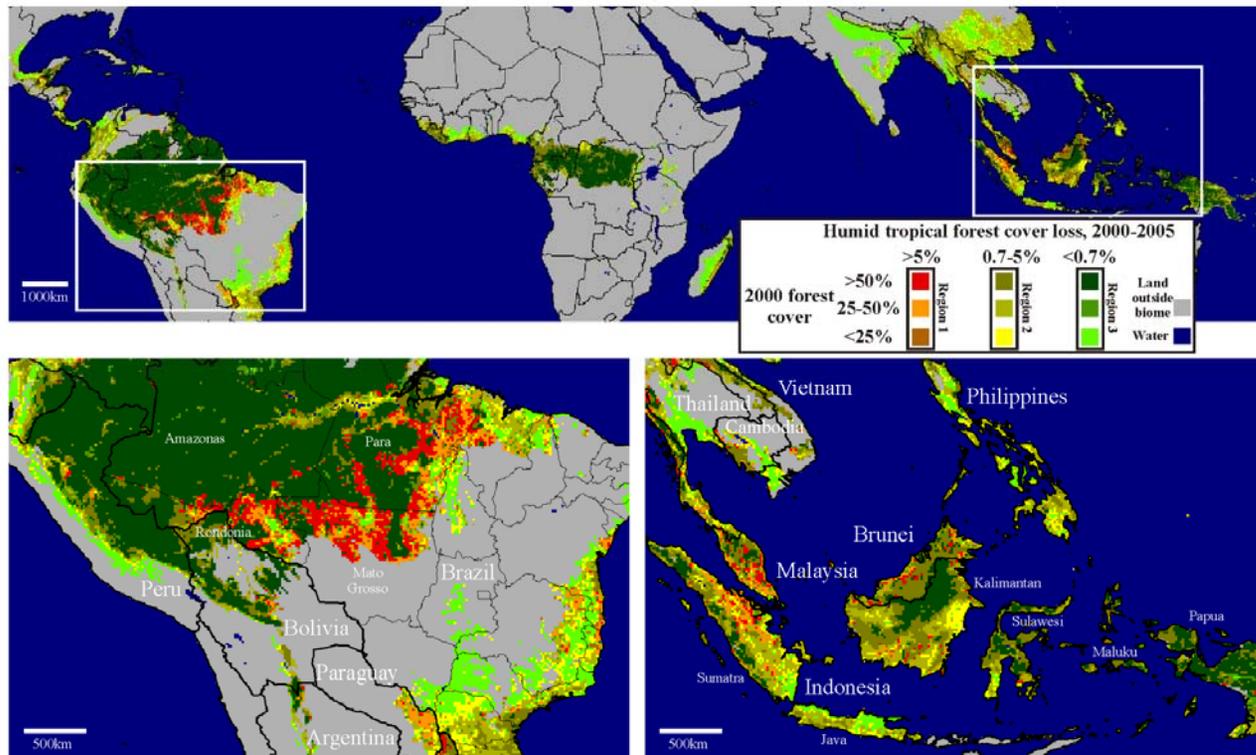
Forest cover loss, 2000 to 2005

Sumatra & Kalimantan, 2000 to 2005

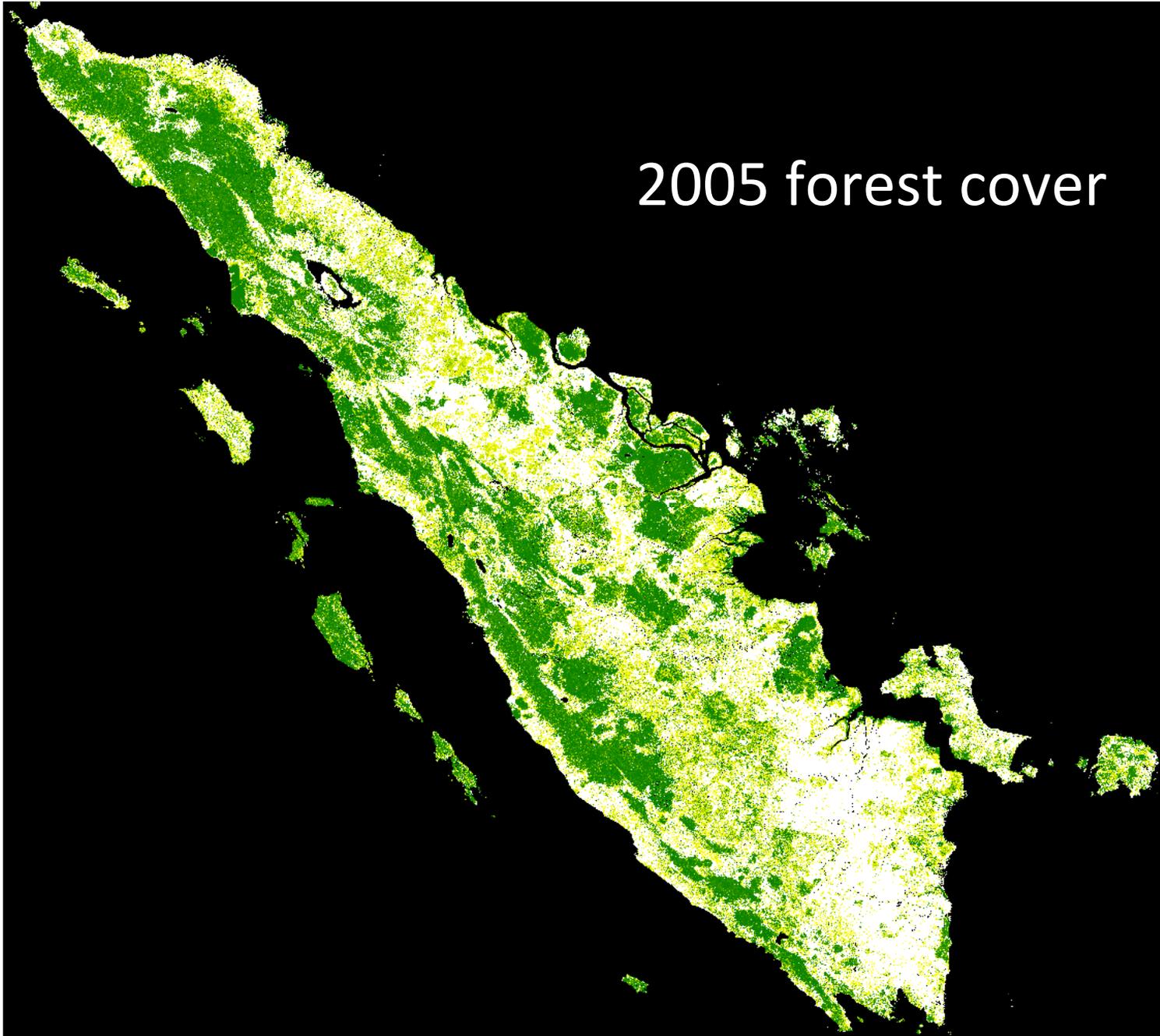
- Sample-based change – 0.60% (+/-0.08)
- Exhaustive mapping estimate – 0.56%

Congo Basin, 2000 to 2005

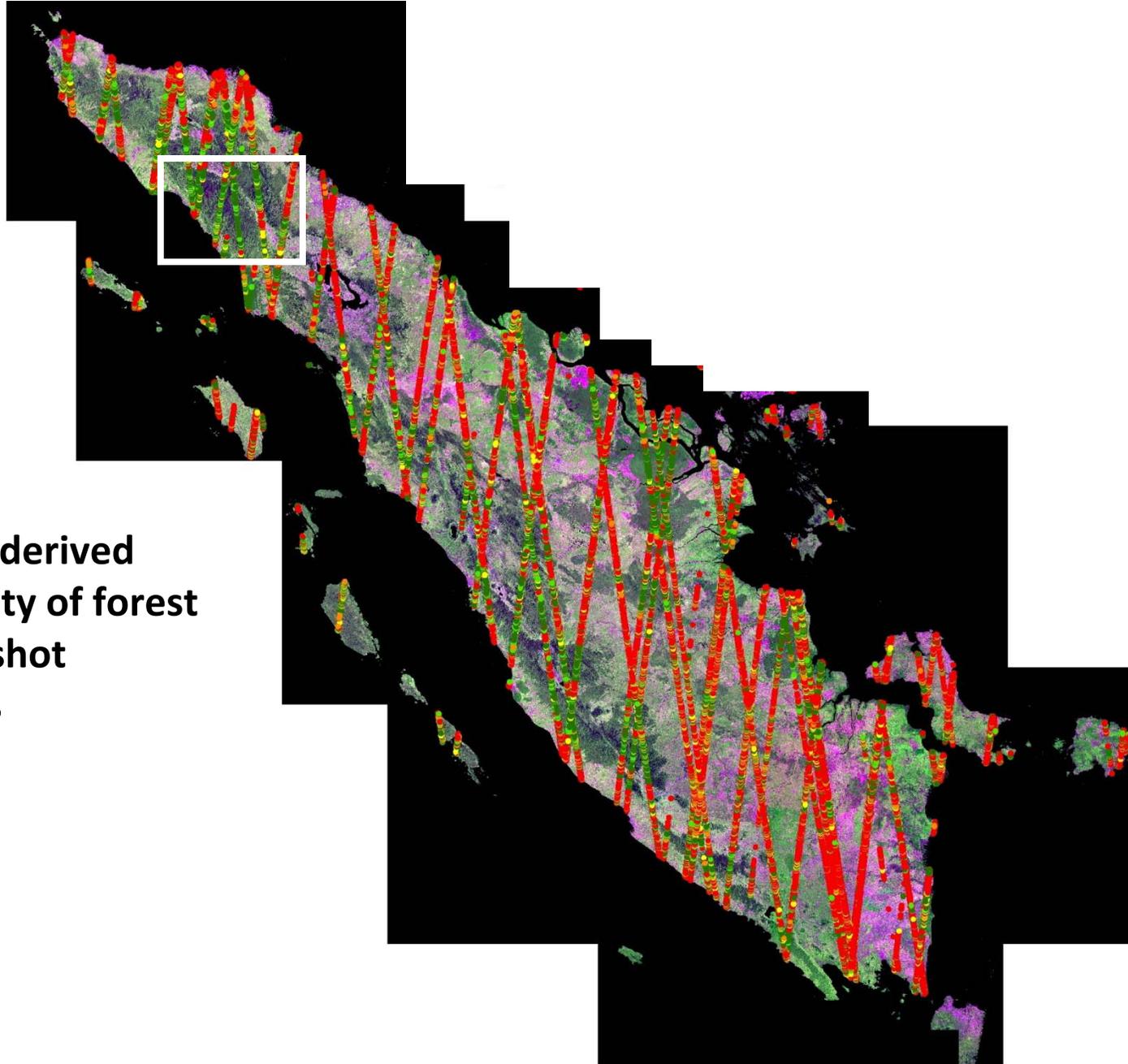
- Sample-based change (DRC only) – 0.12% (+/-0.12%)
- Exhaustive mapping estimate – 0.12%



2005 forest cover



GLAS shots over Sumatra, Indonesia on Landsat 2004-2006 composite 5/4/7



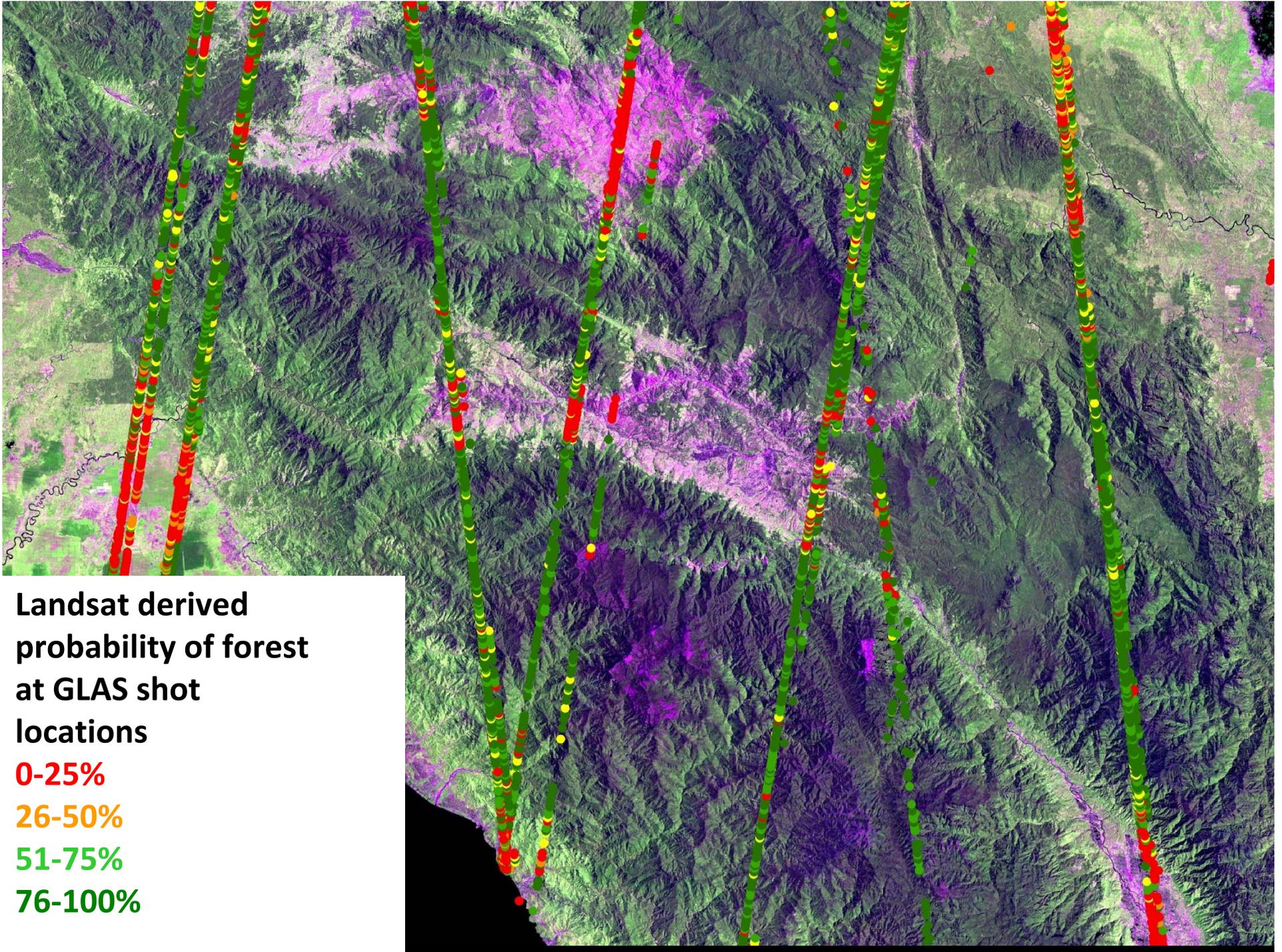
Landsat derived
probability of forest
at GLAS shot
locations

0-25%

26-50%

51-75%

76-100%



**Landsat derived
probability of forest
at GLAS shot
locations**

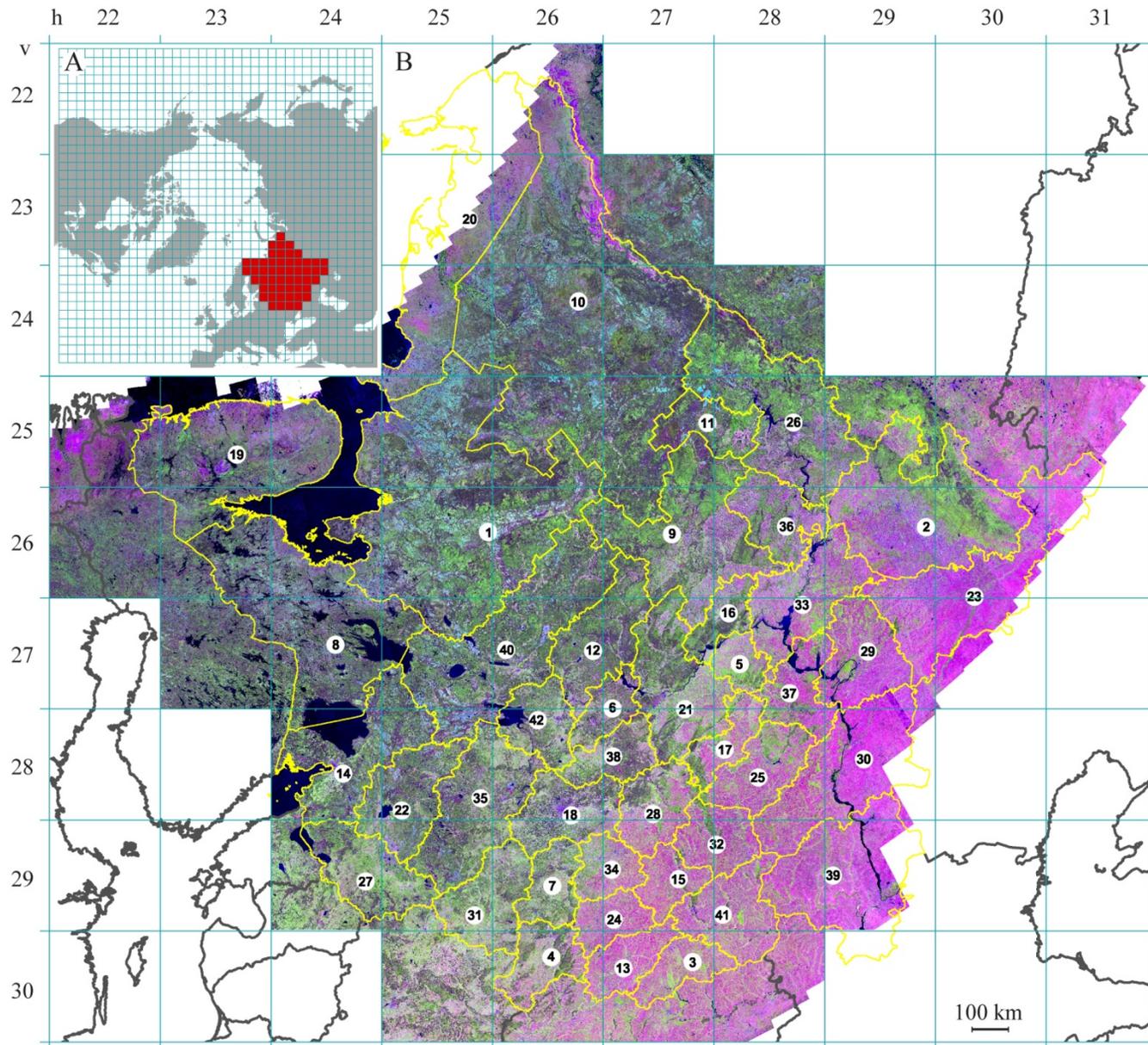
0-25%

26-50%

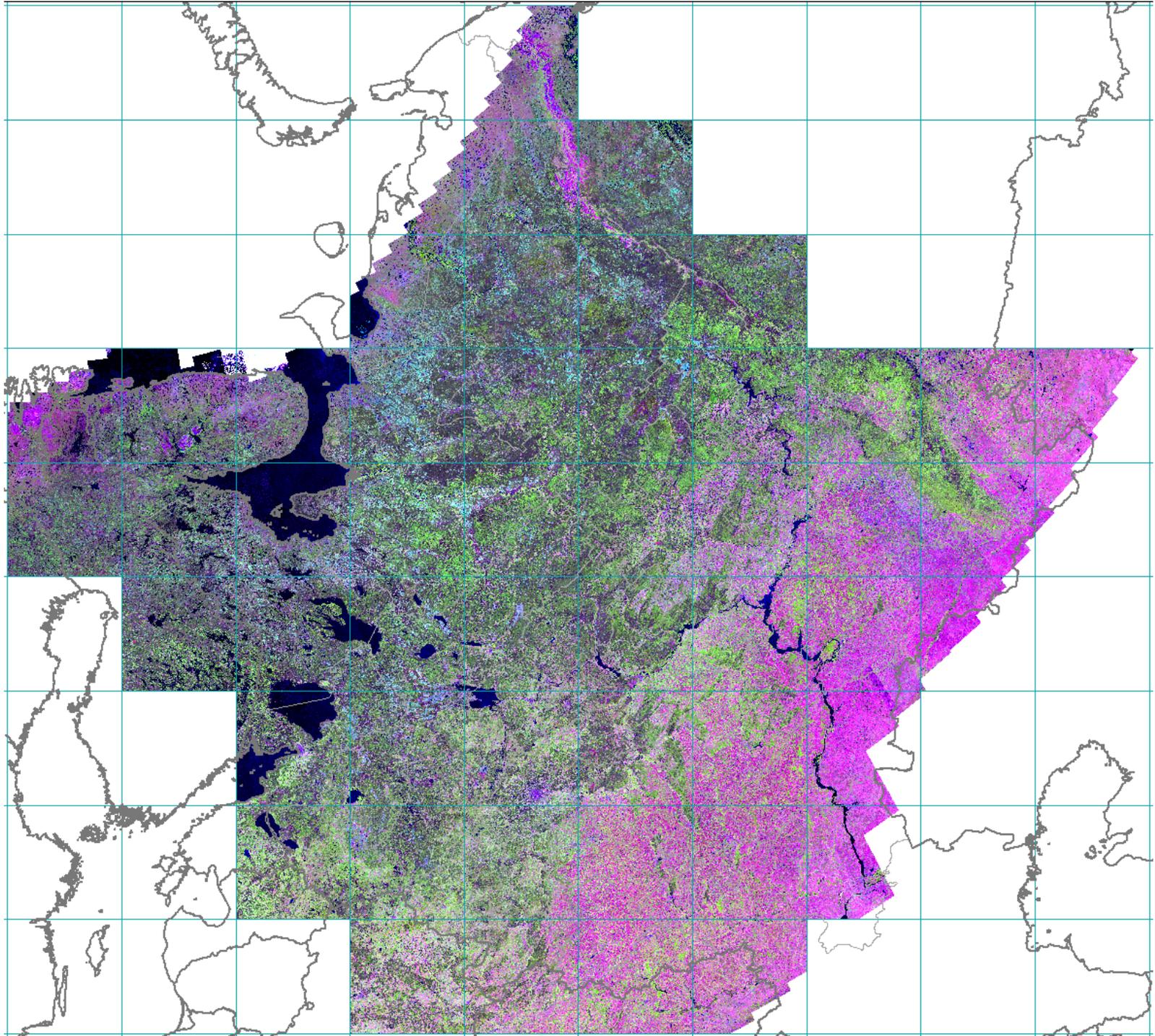
51-75%

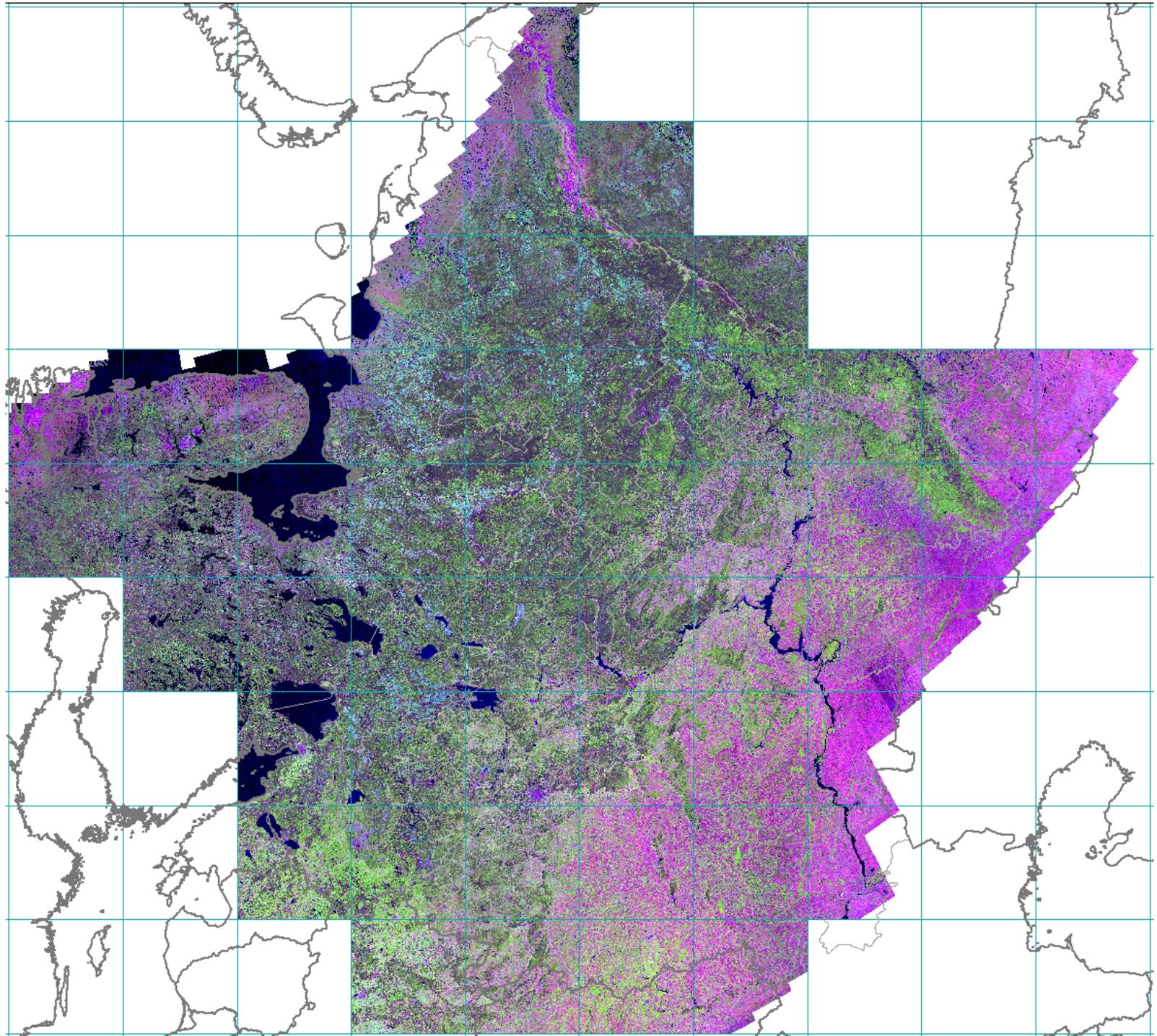
76-100%

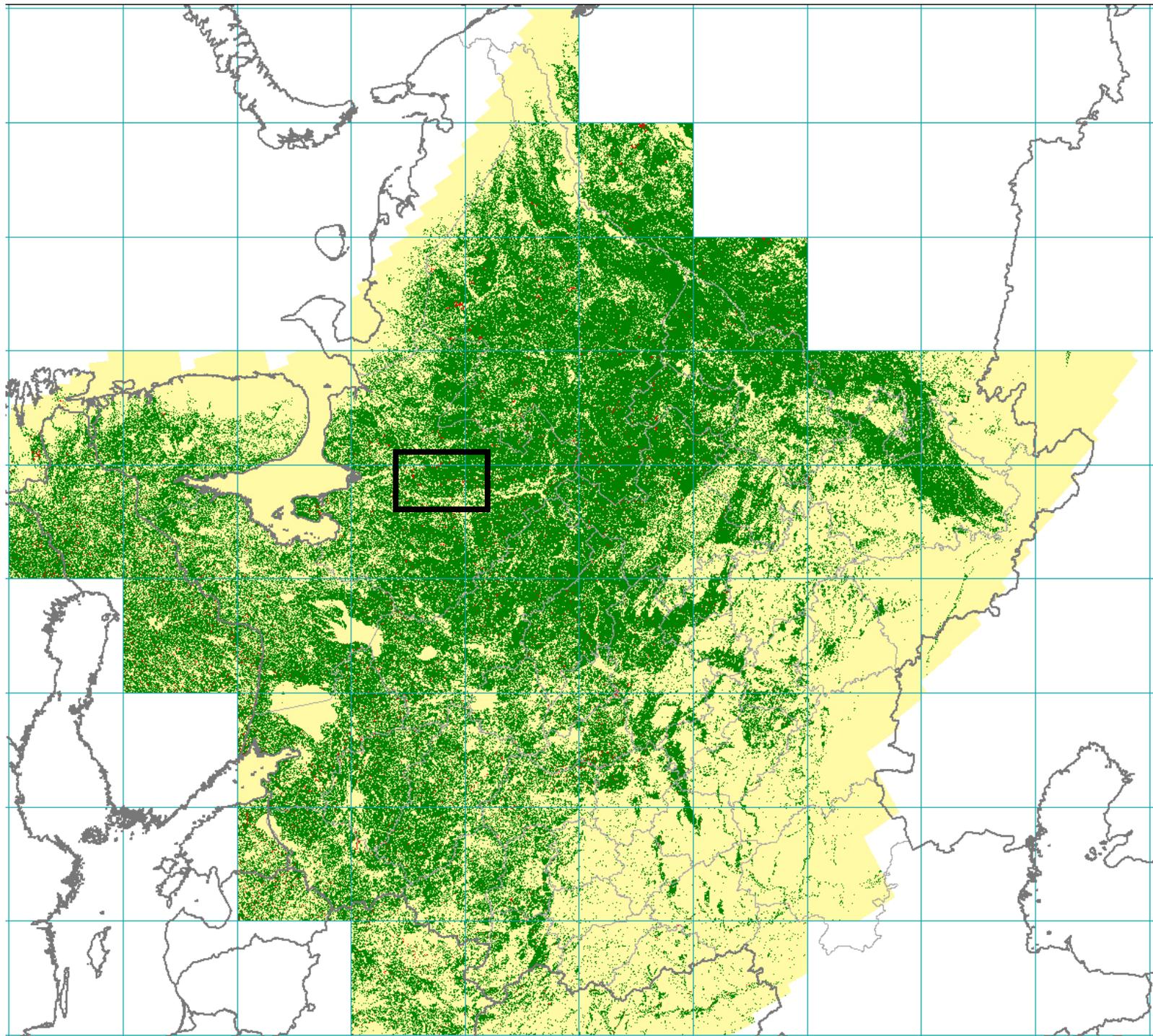
MDGLS – Boreal forest cover and change

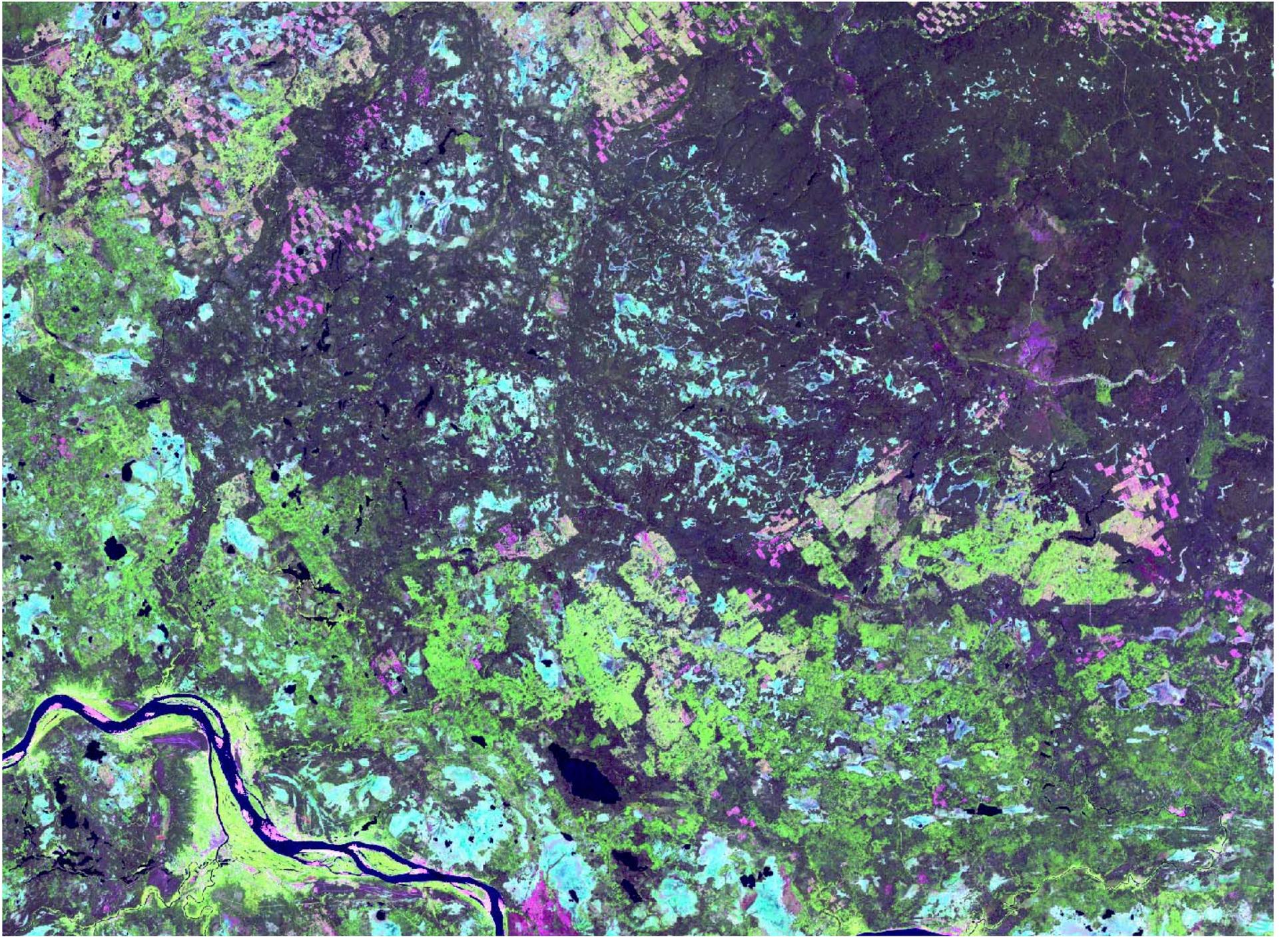


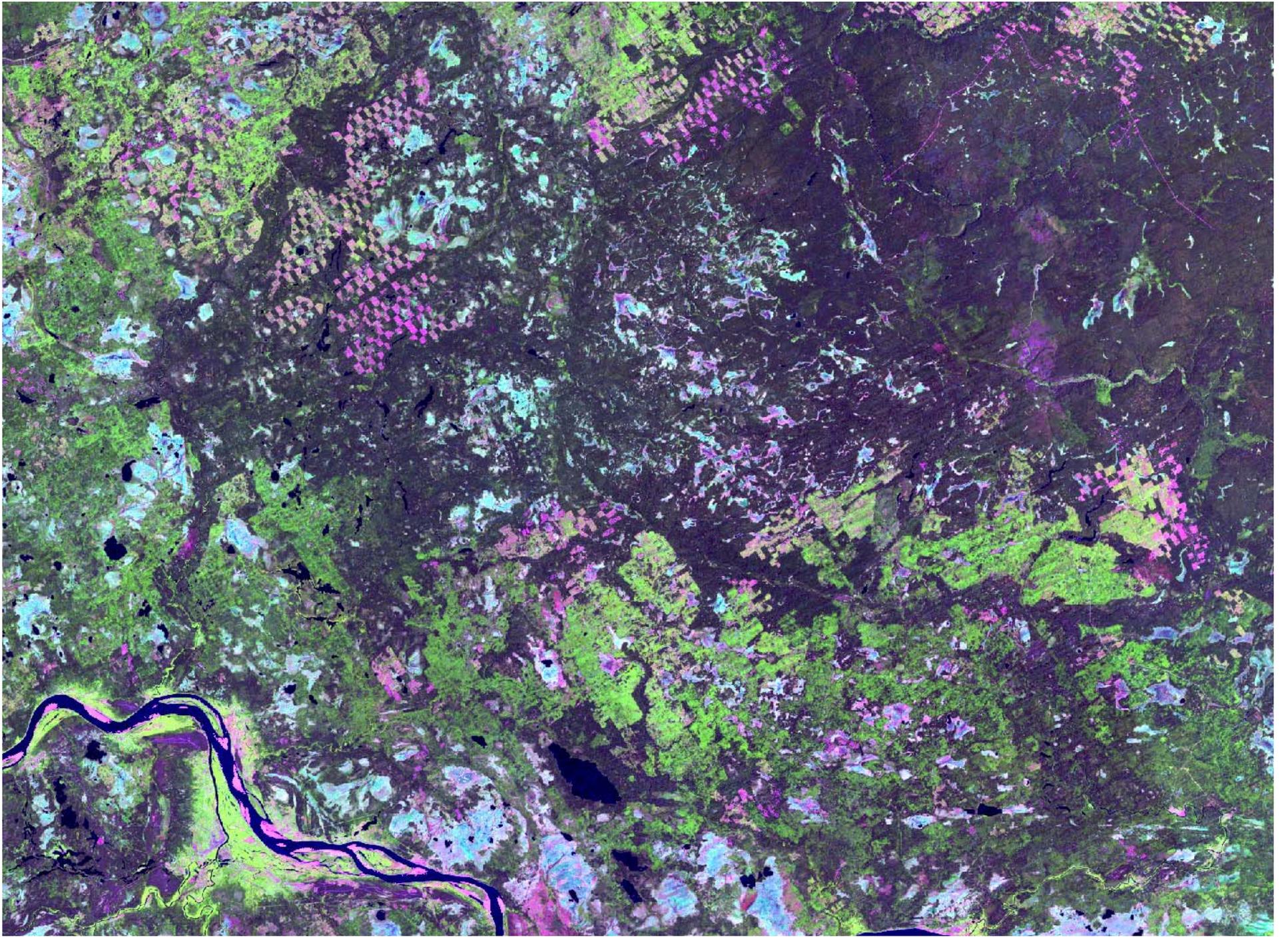
7227
images
2000-2005

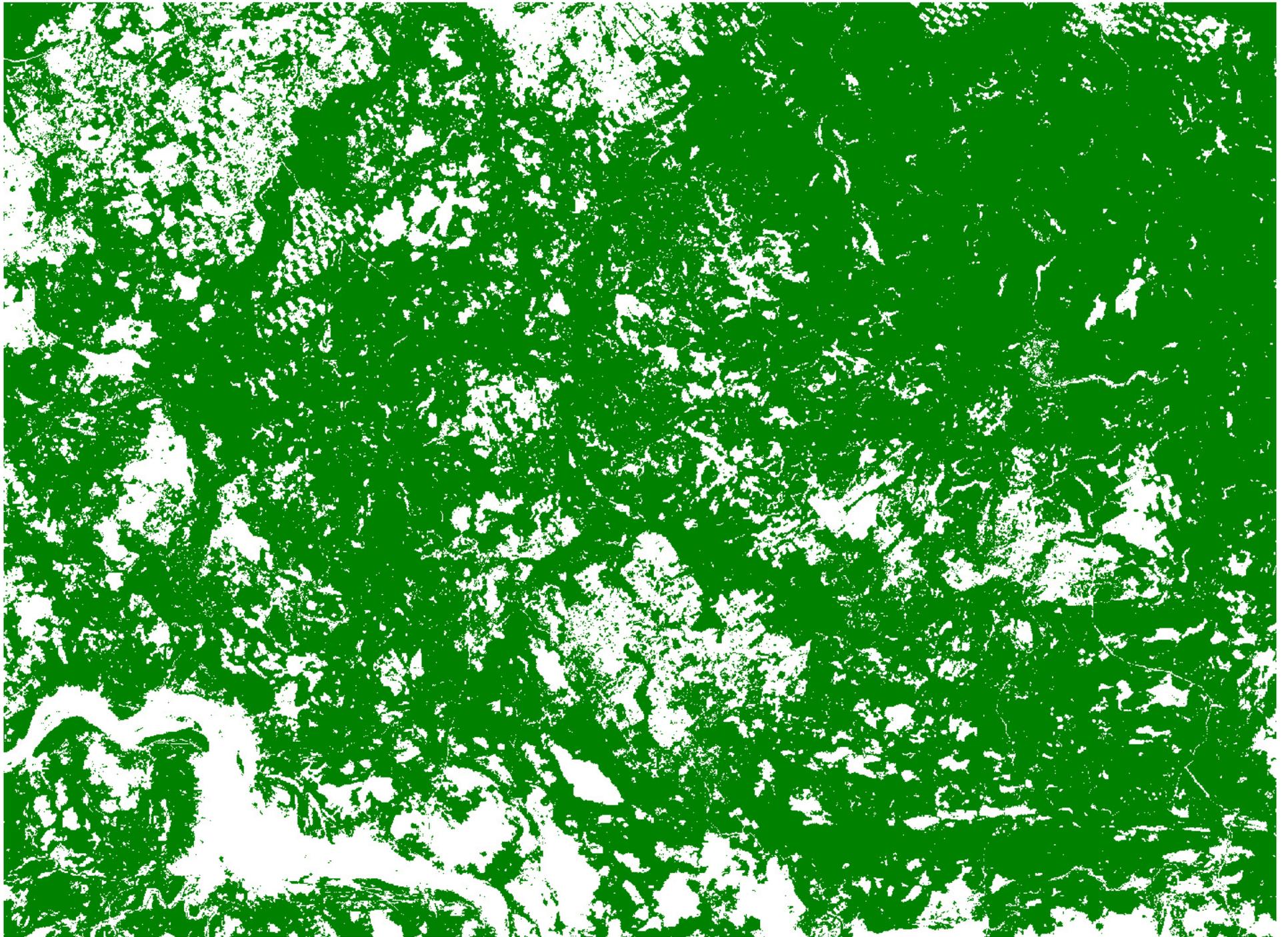


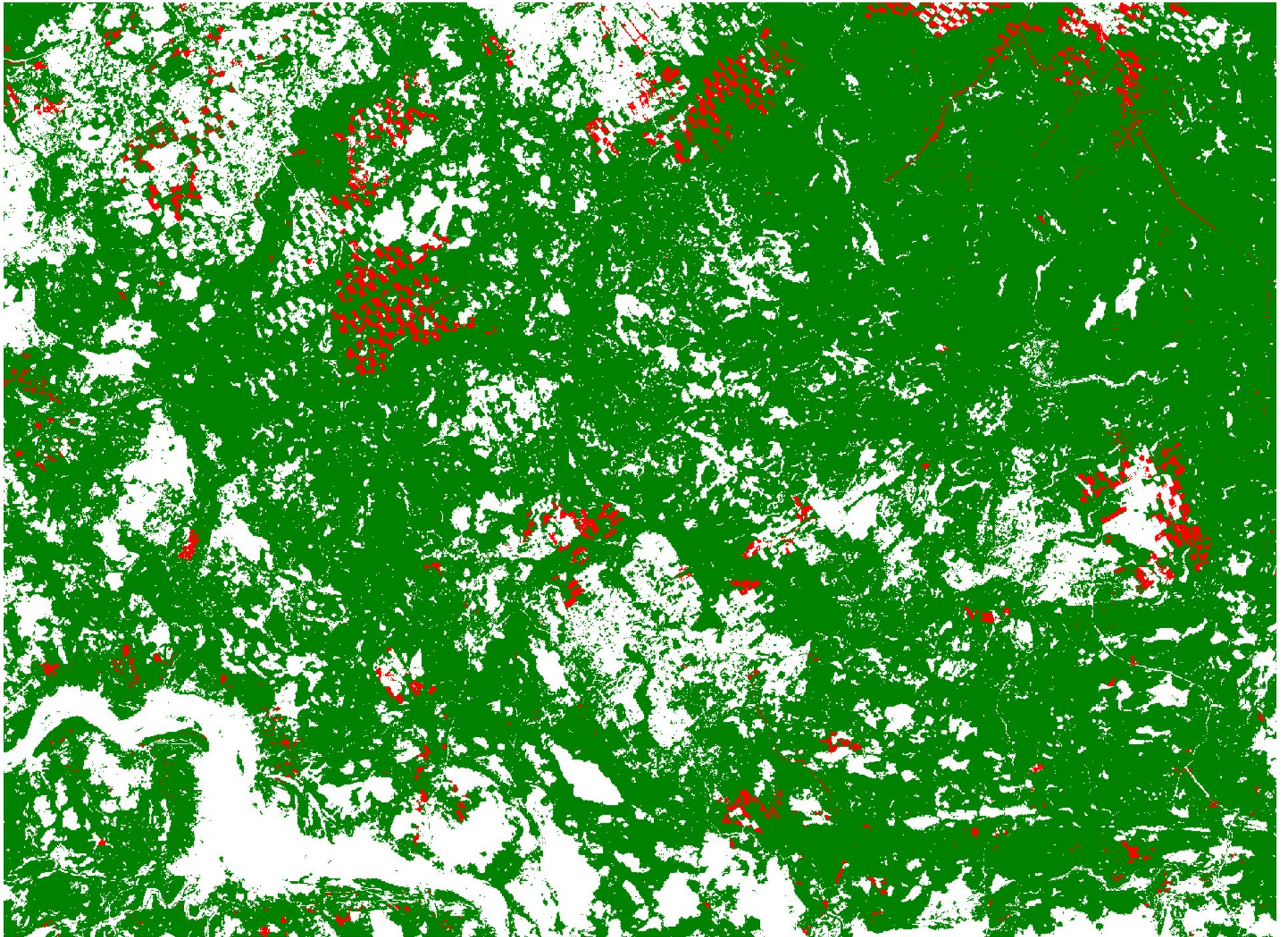


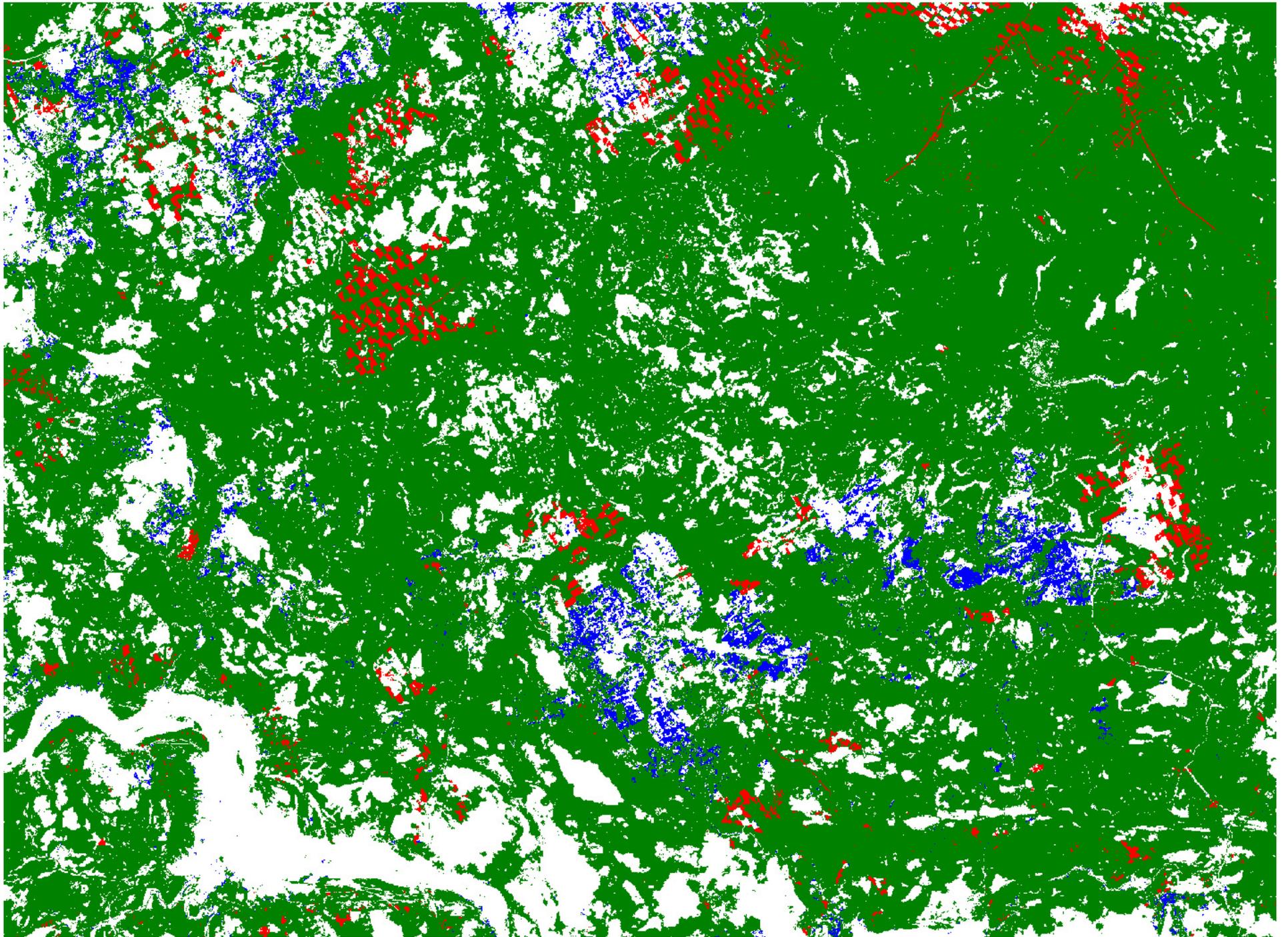




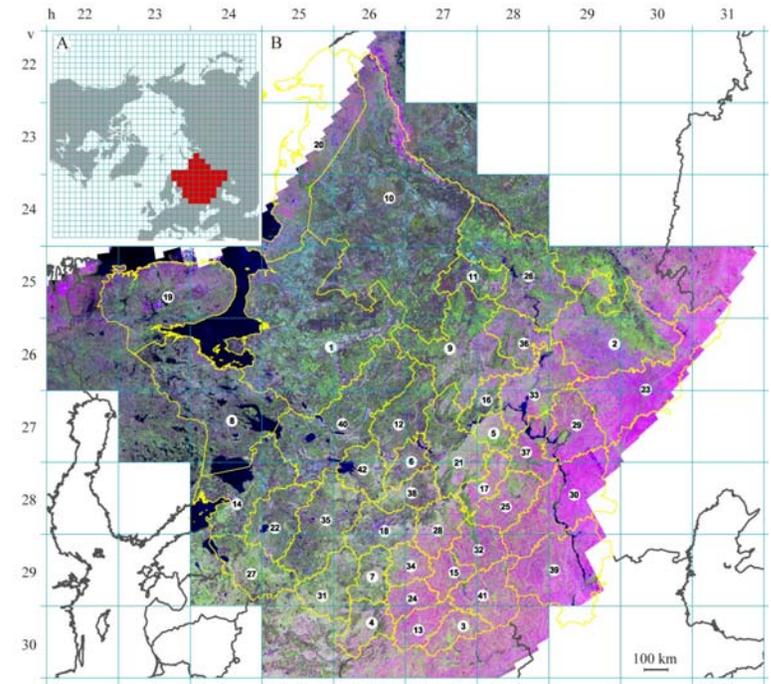
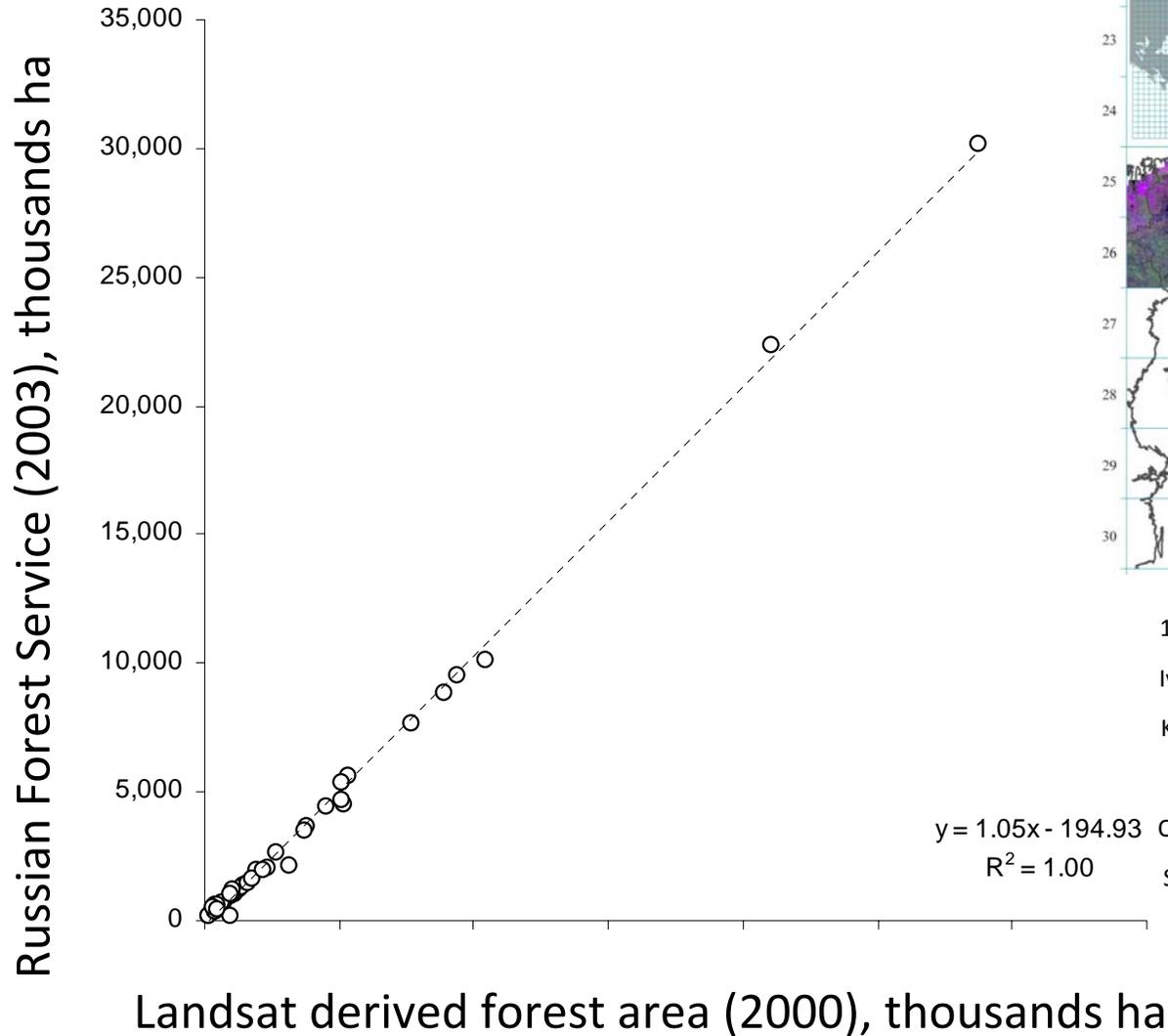






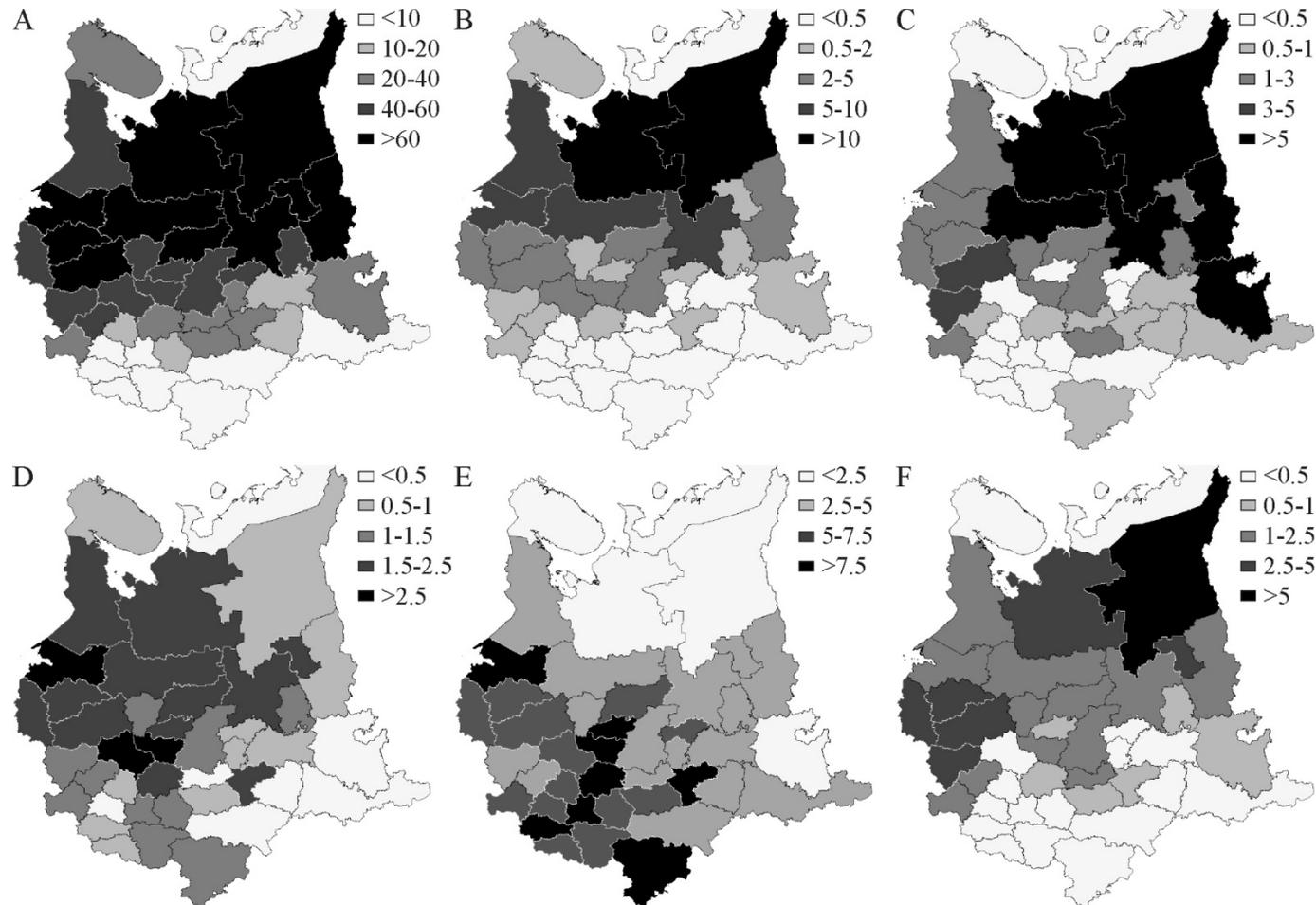


Forest area comparison by administrative region

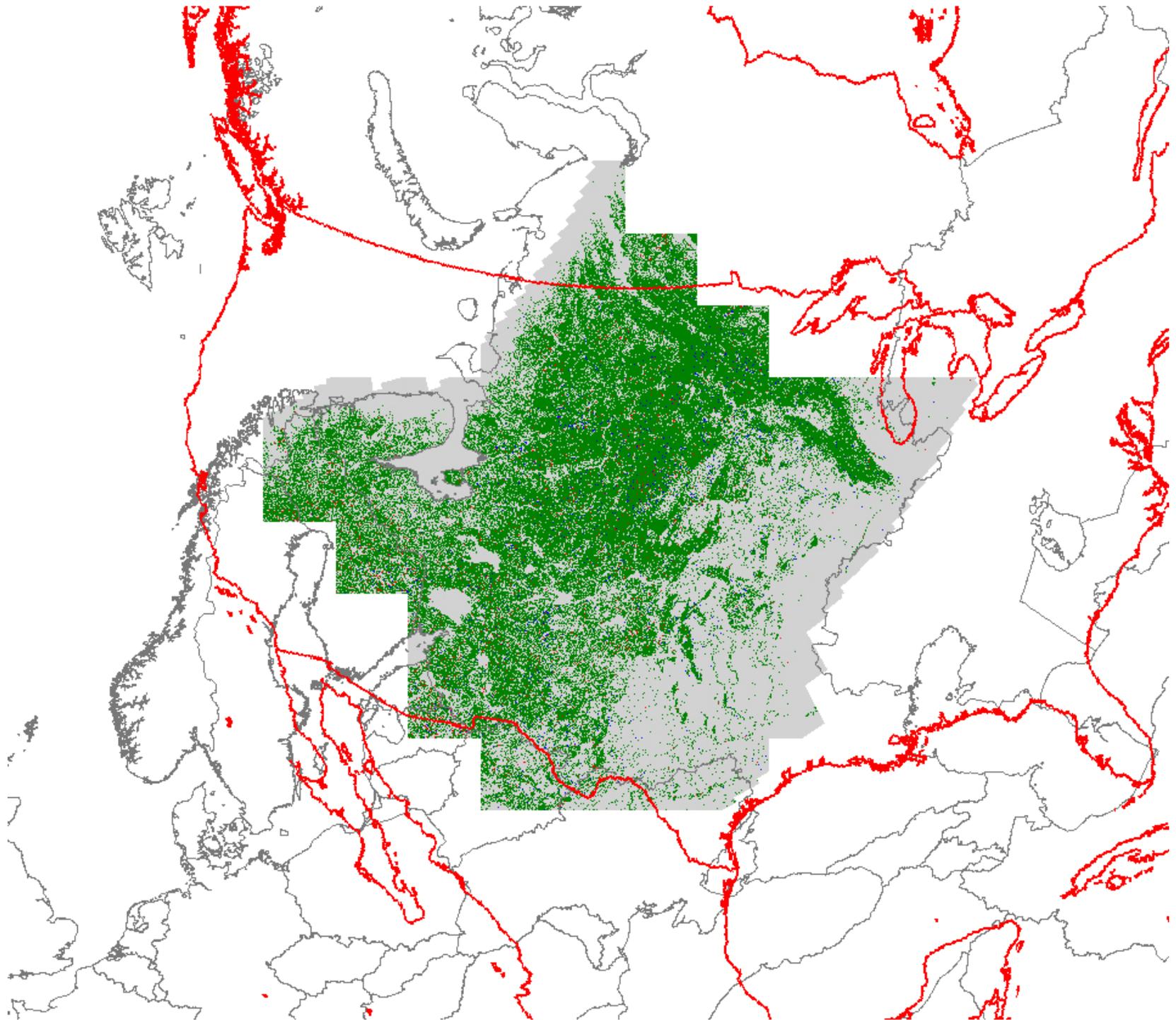


- 1 Arkhangelskaya Oblast (Ob); 2 Bashkortostan Republic (Rp); 3 Belgorodskaya Ob; 4 Bryanskaya Ob; 5 Chuvashiya Rp; 6 Ivanovskaya Ob; 7 Kaluzhskaya Ob; 8 Kareliya Rp; 9 Kirovskaya Ob; 10 Komi Rp; 11 Komi-Permyatskiy Okrug (Okr); 12 Kostromskaya Ob; 13 Kurskaya Ob; 14 Leningradskaya Ob; 15 Lipetskaya Ob; 16 Mariy-El Rp; 17 Mordoviya Rp; 18 Moskovskaya Ob; 19 Murmanskaya Ob; 20 Nenetskiy Ok; 21 Nizhegorodskaya Ob; 22 Novgorodskaya Ob; 23 Orenburgskaya Ob; 24 Orlovskaya Ob; 25 Penzenskaya Ob; 26 Permskaya Ob; 27 Pskovskaya Ob; 28 Ryazanskaya Ob; 29 Samarskaya Ob; 30 Saratovskaya Ob; 31 Smolenskaya Ob; 32 Tambovskaya Ob; 33 Tatarstan Rp; 34 Tulsckaya Ob; 35 Tverskaya Obl; 36 Udmurtiya Rp; 37 Ulyanovskaya Ob; 38 Vladimirskaya Ob; 39 Volgogradskaya Ob; 40 Vologodskaya Ob; 41 Voronezhskaya Ob; 42 Yaroslavsckaya Ob.

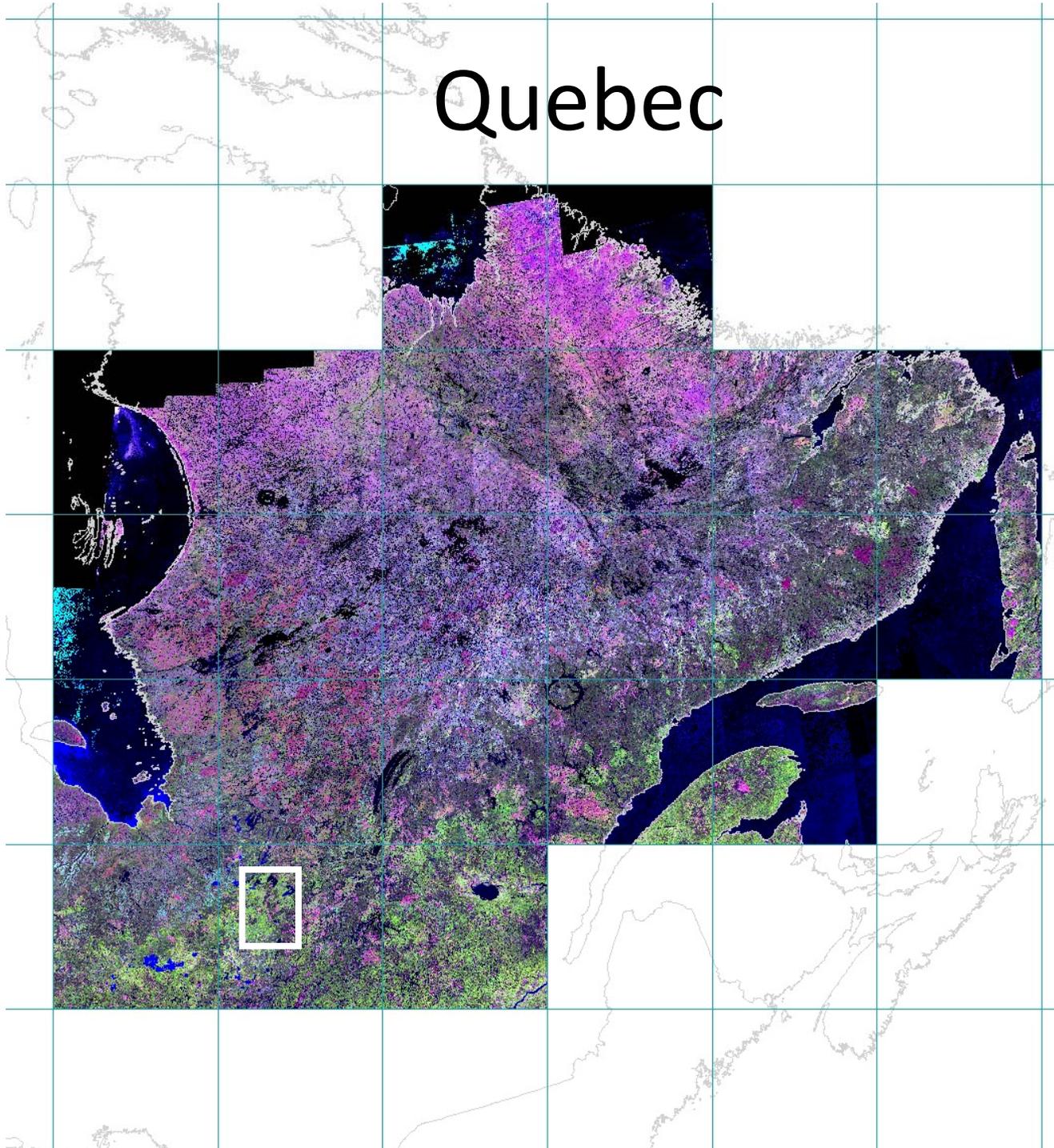
MDGLS forest cover monitoring results – European Russia



- A. Forest cover area for circa year 2000 as percent of the region's area.
- B. Region's forest cover loss 2000-2005 as percent of total forest cover loss area within European Russia.
- C. Region's forest cover gain 2000-2005 as percent of total forest cover gain within European Russia.
- D. Forest cover loss 2000-2005 as percent of forest cover circa year 2000 within the region.
- E. Forest cover loss patch density (patches per thousand hectares).
- F. Forest cover gain detected within circa 2000 cropland areas as percent of total cropland areas circa 2000 within the region.



Quebec





Conclusions

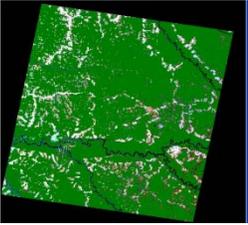
- Our capacity for monitoring forest change at national to global scales with remotely sensed data is quickly maturing (nearly operational)
 - generic methods are possible, ensuring consistency between nations/regions
- Data used for monitoring must include 1) systematic global acquisitions and data provision at 2) no cost and with 3) easy access
 - This allows for sharing of methods, again ensuring consistency between nations/regions
- Few systems meet these requirements -- preamble of any talk on a new sensing system should start with data policy, not engineering specifications

Acknowledgments

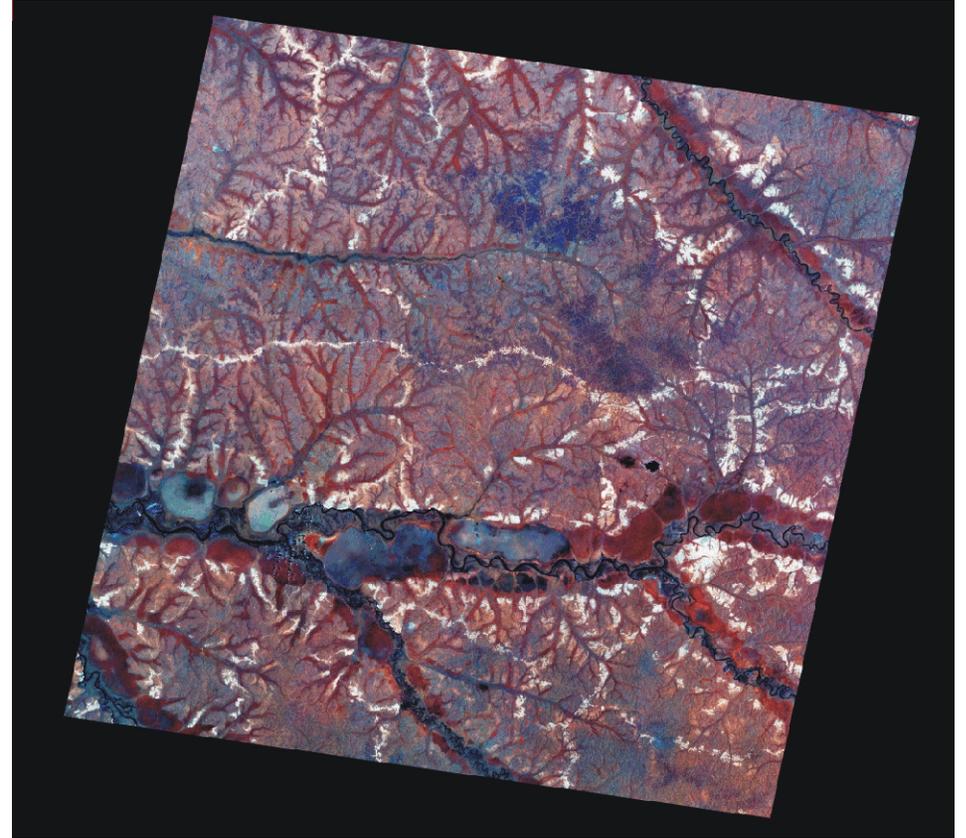
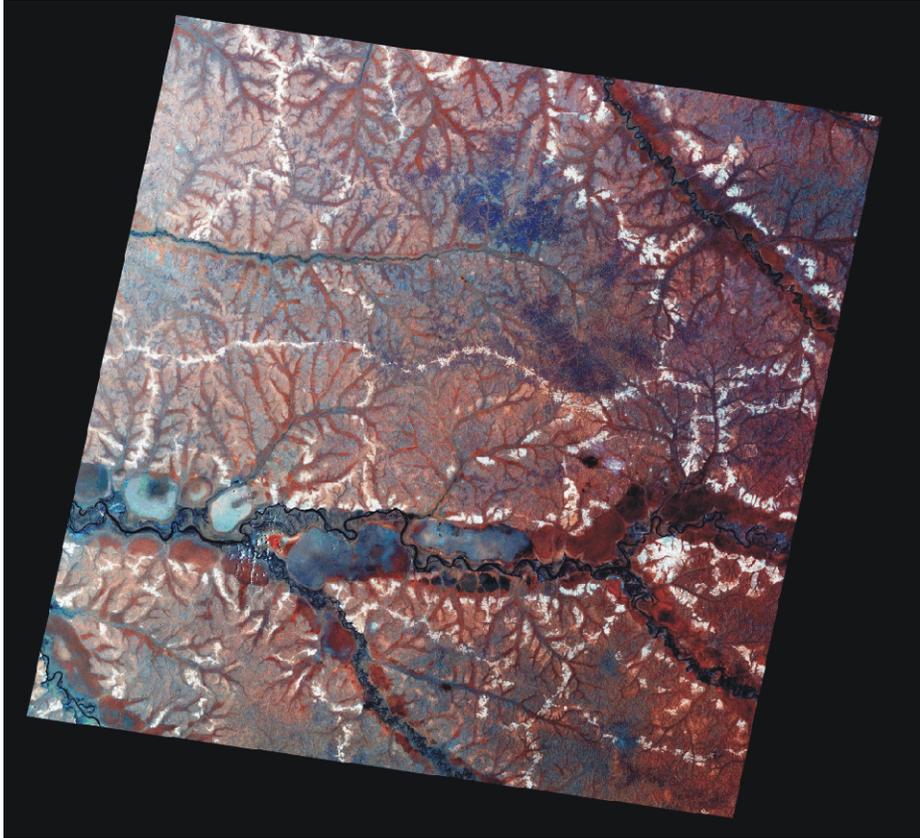
- NASA
- USGS
- USAID
- Peter Potapov, Mark Broich, Bernard Adusei, Erik Lindquist, Svetlana Turubanova, David Roy, SDSU
- Steve Stehman, SUNY-ESF
- Tom Loveland, USGS
- Chris Justice, John Townshend, UMd
- Ruth DeFries, Columbia



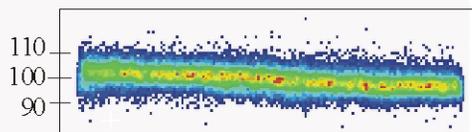
Forest mask from MODIS



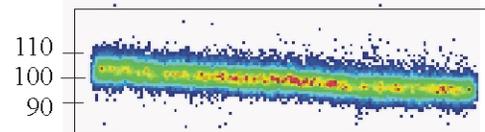
BRDF correction



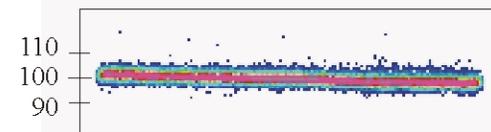
digital numbers



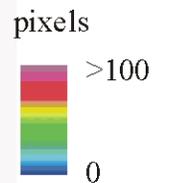
band 4 cross-track pixels

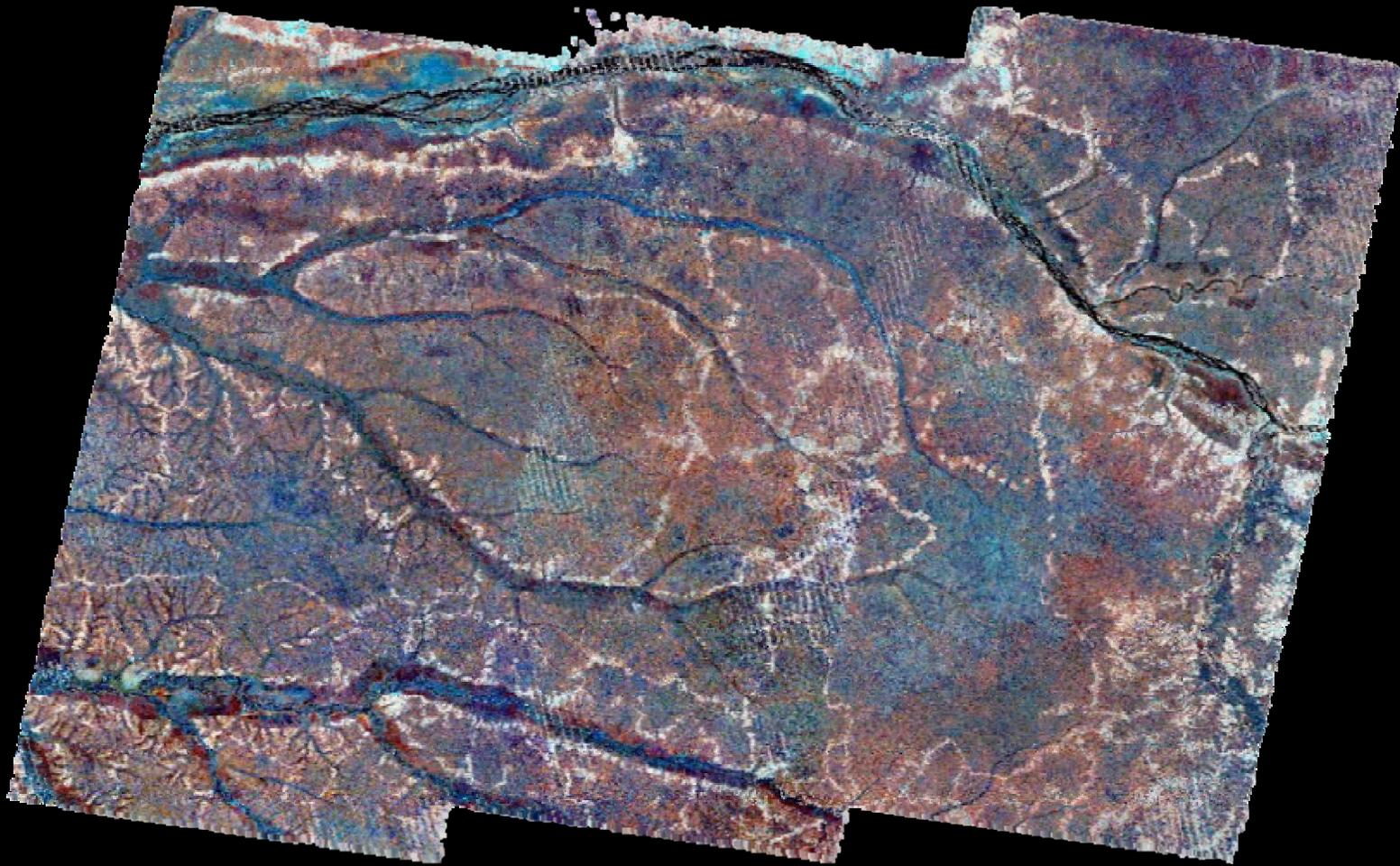


band 5 cross-track pixels



band 7 cross-track pixels

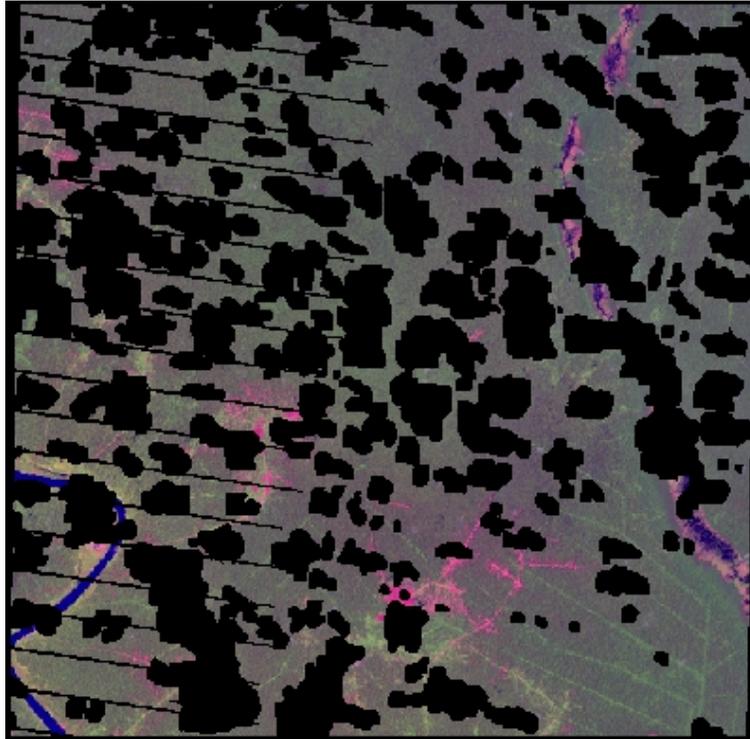




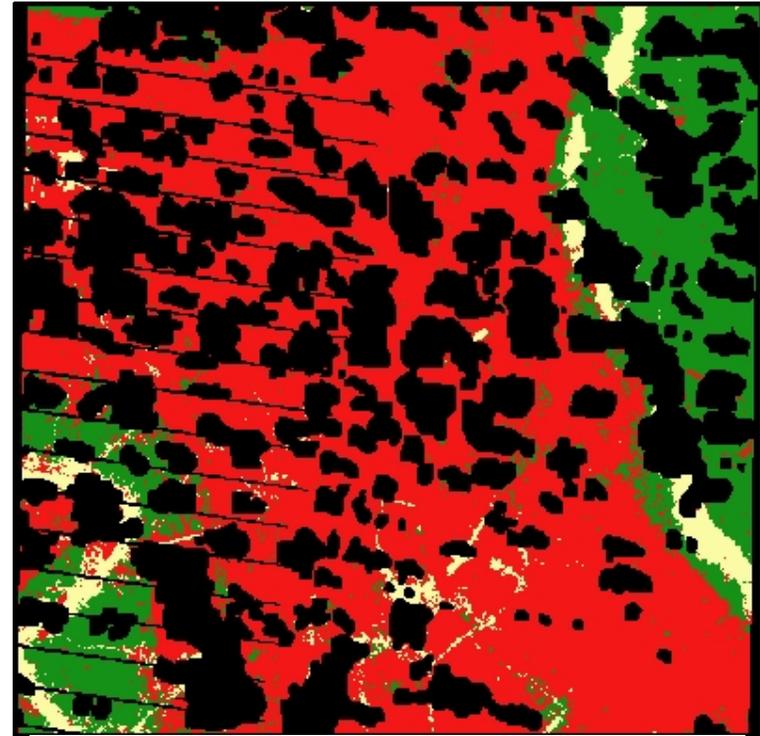
1 2 3 4 5

2005 epoch with SLC-off data

Sample block in Riau: Intact forest loss and agro-forestry

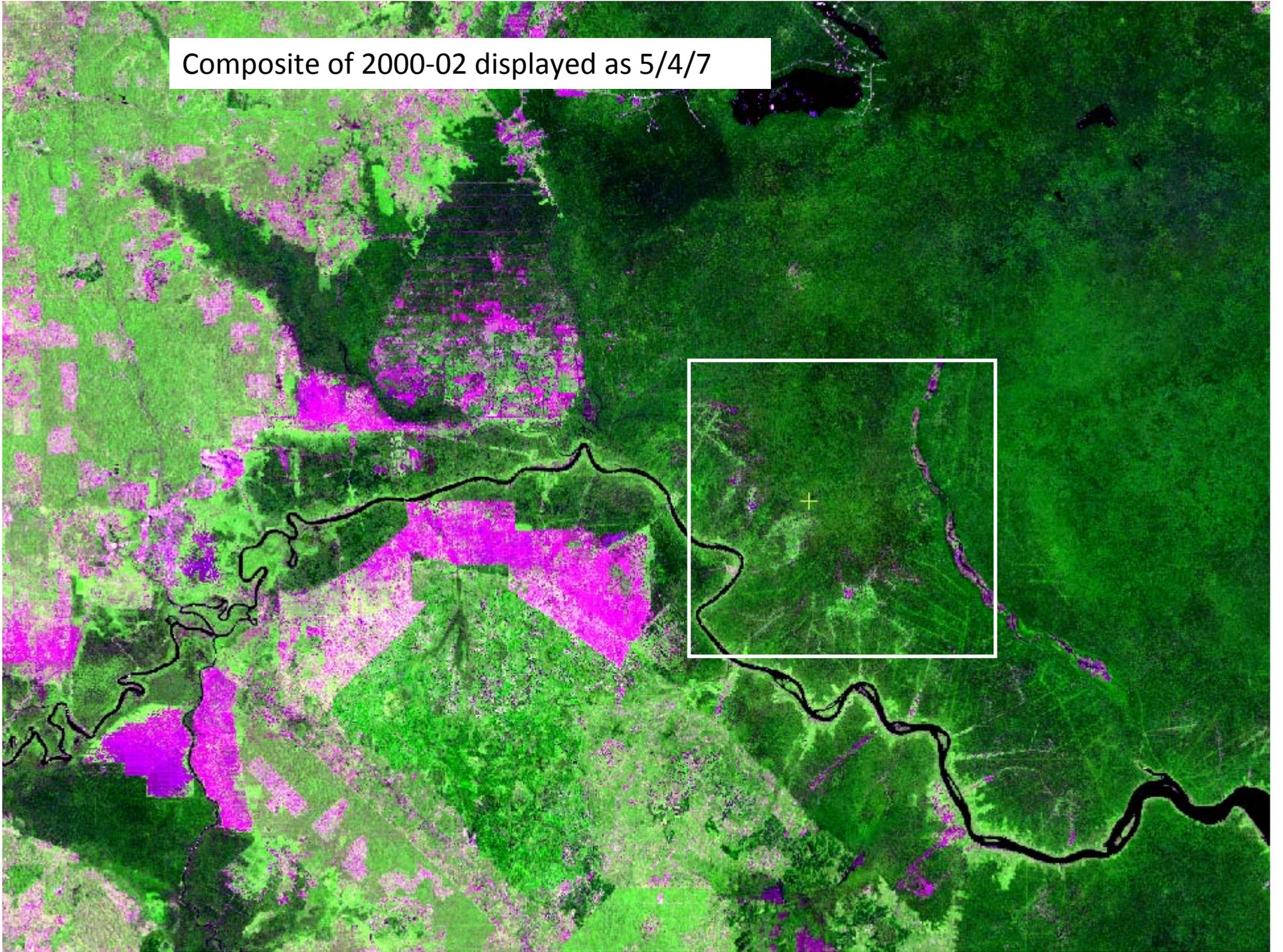


2000

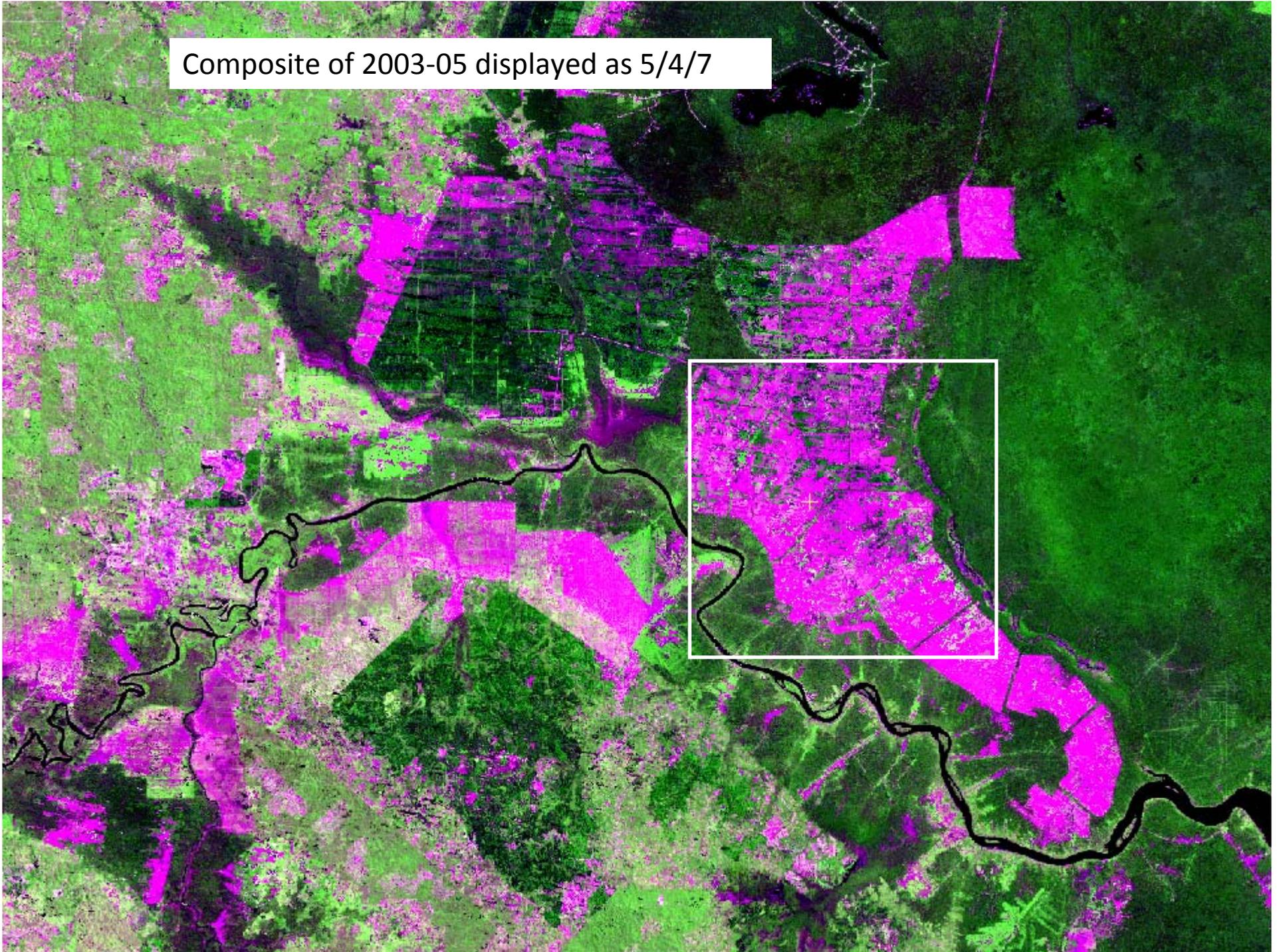


Expert interpretation:
Green = forest in 2000
Yellow = no forest in 2000
Red = forest cover loss 2000-05

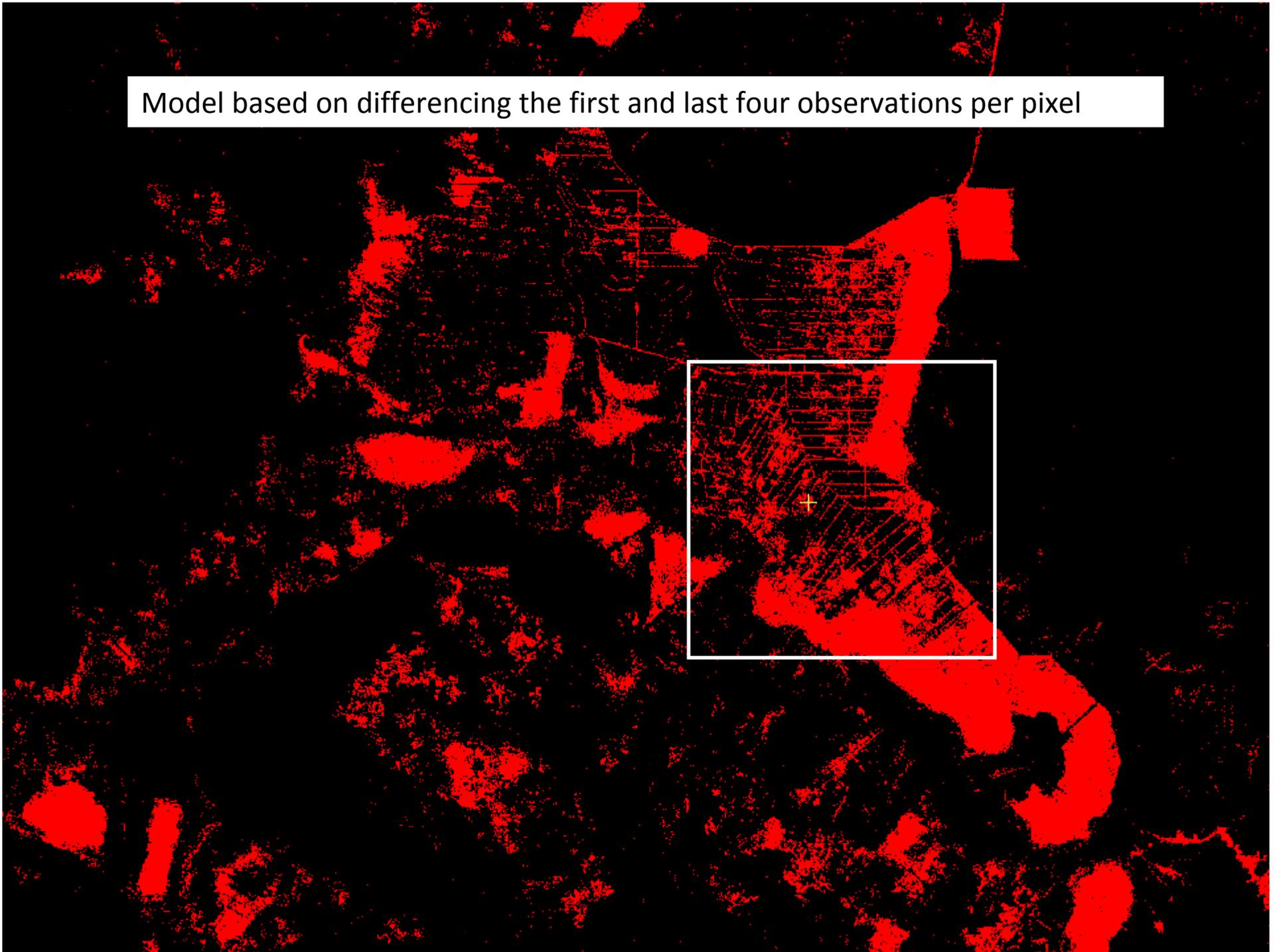
Composite of 2000-02 displayed as 5/4/7



Composite of 2003-05 displayed as 5/4/7



Model based on differencing the first and last four observations per pixel



Model based on full time series analysis per pixel

