Central Africa Regional Program for the Environment

NASA/UMd/OSFAC consortium

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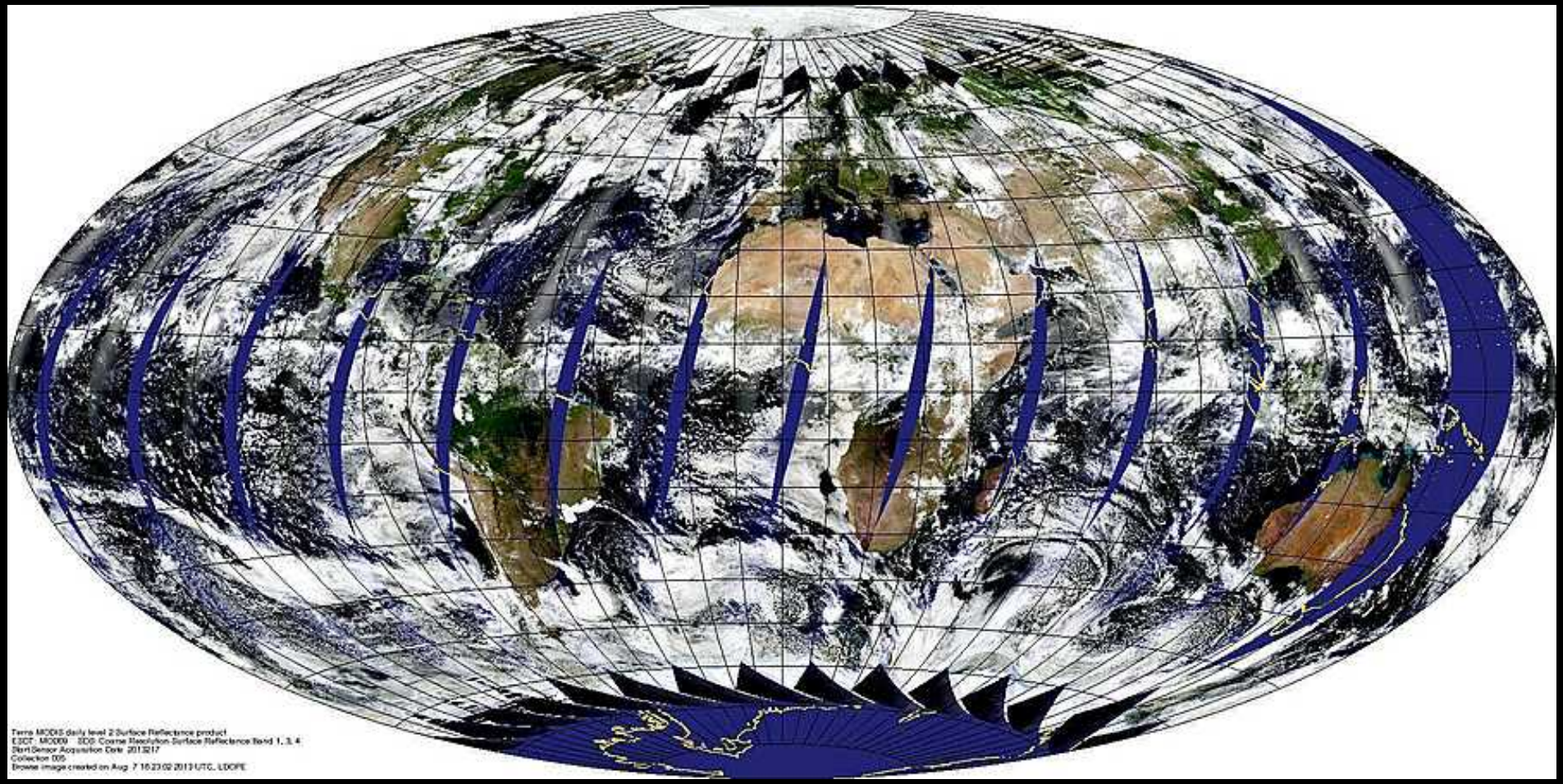
CARPE II tasks

- Establish regional-scale Landsat forest cover monitoring system
- Disseminate data and products
- Institutionalize forest cover monitoring capacity at OSFAC
- Move OSFAC towards independence and sustainability
- Collaborate with other CARPE partners in integrating earth observation data and products in decision support systems and analysis
- Enroll and graduate PhD and Masters students from the region
- Manage CARPE website, data portal, web mapping services and information management tool

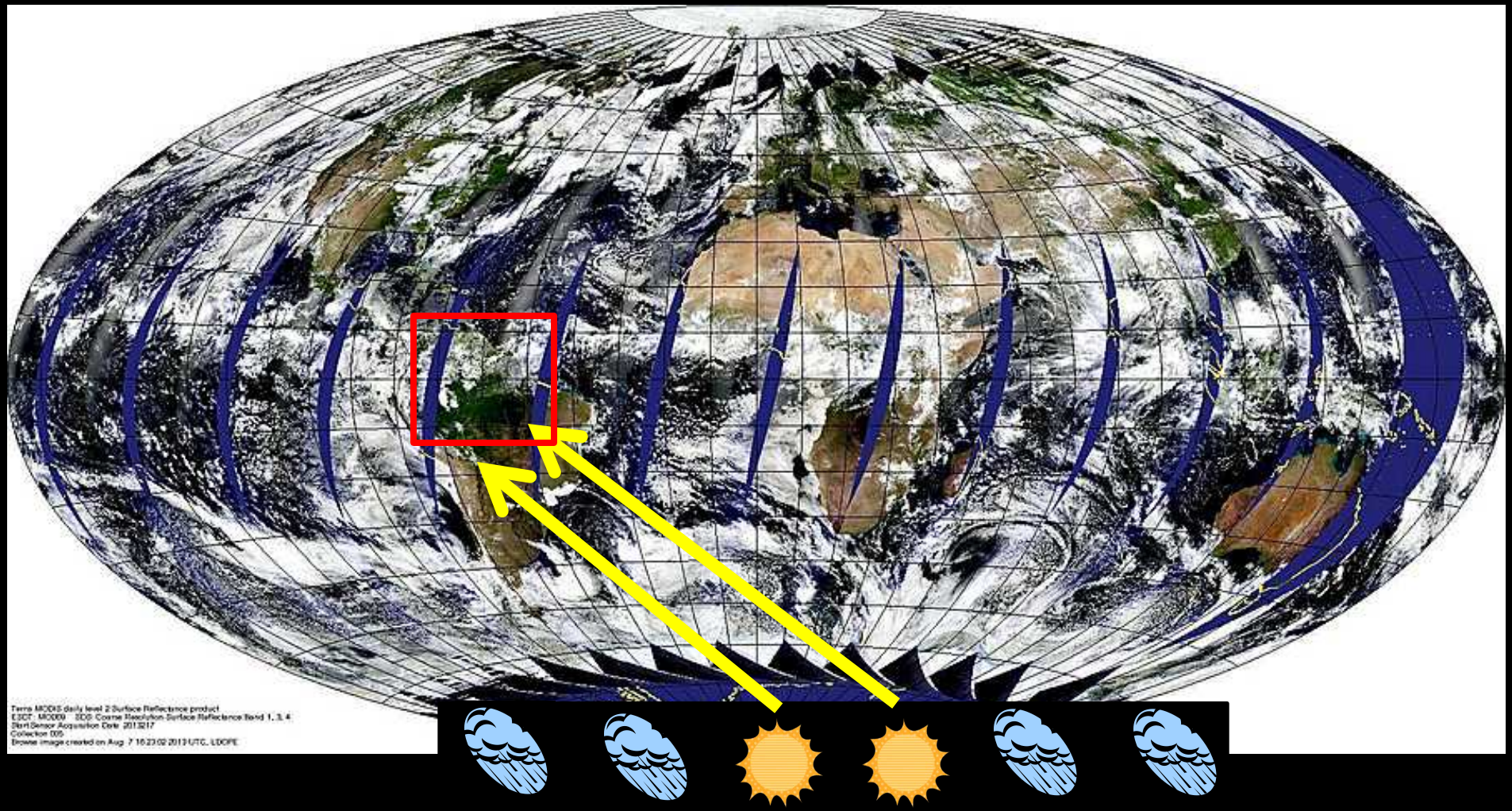
Data requirements for large area land monitoring

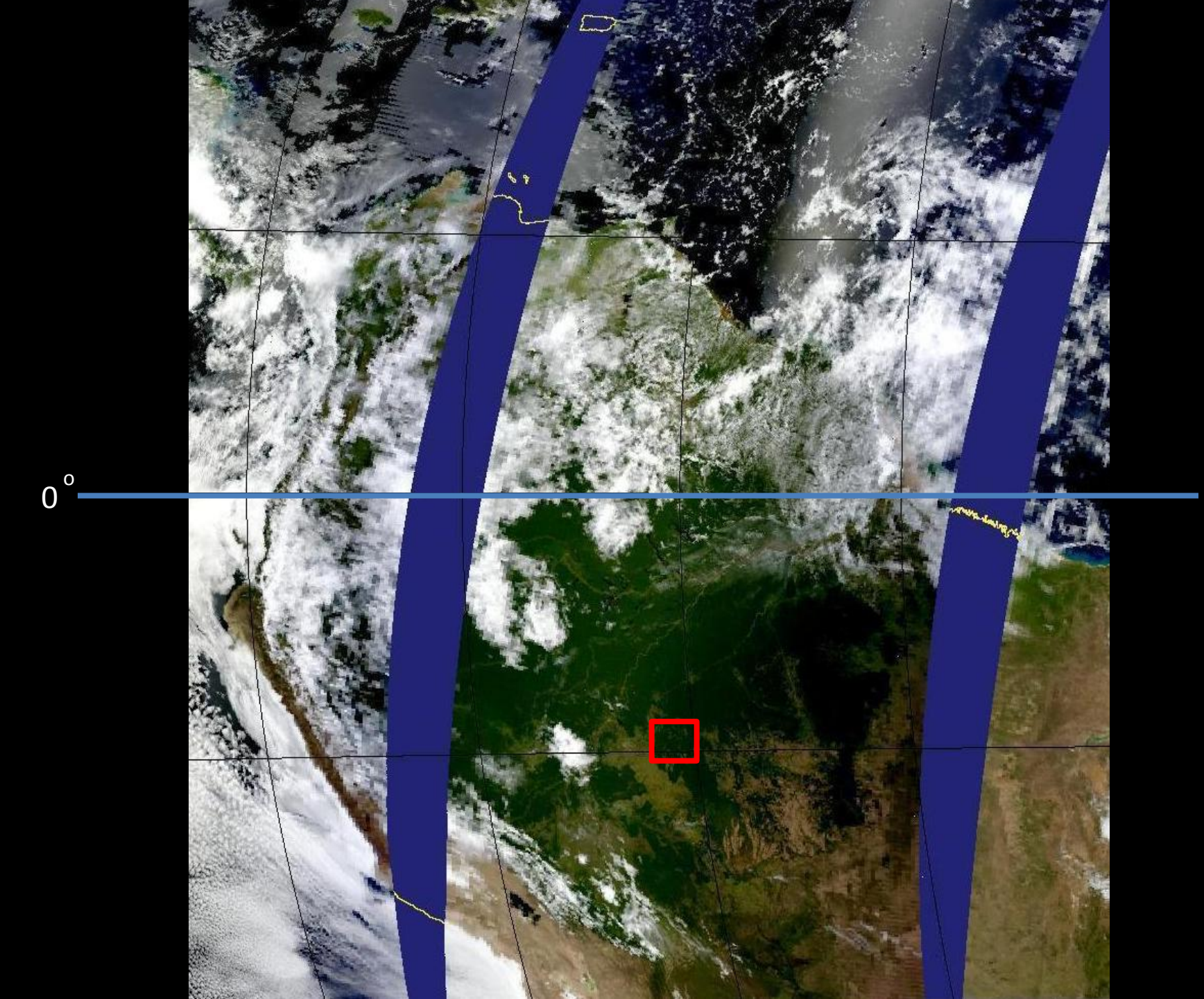
- Systematic global acquisitions
- No/low cost
- Easy access
- Minimal pre-processing required

Daily MODIS image for August 5, 2013



Seasonally cloud-free window over the southern Amazon

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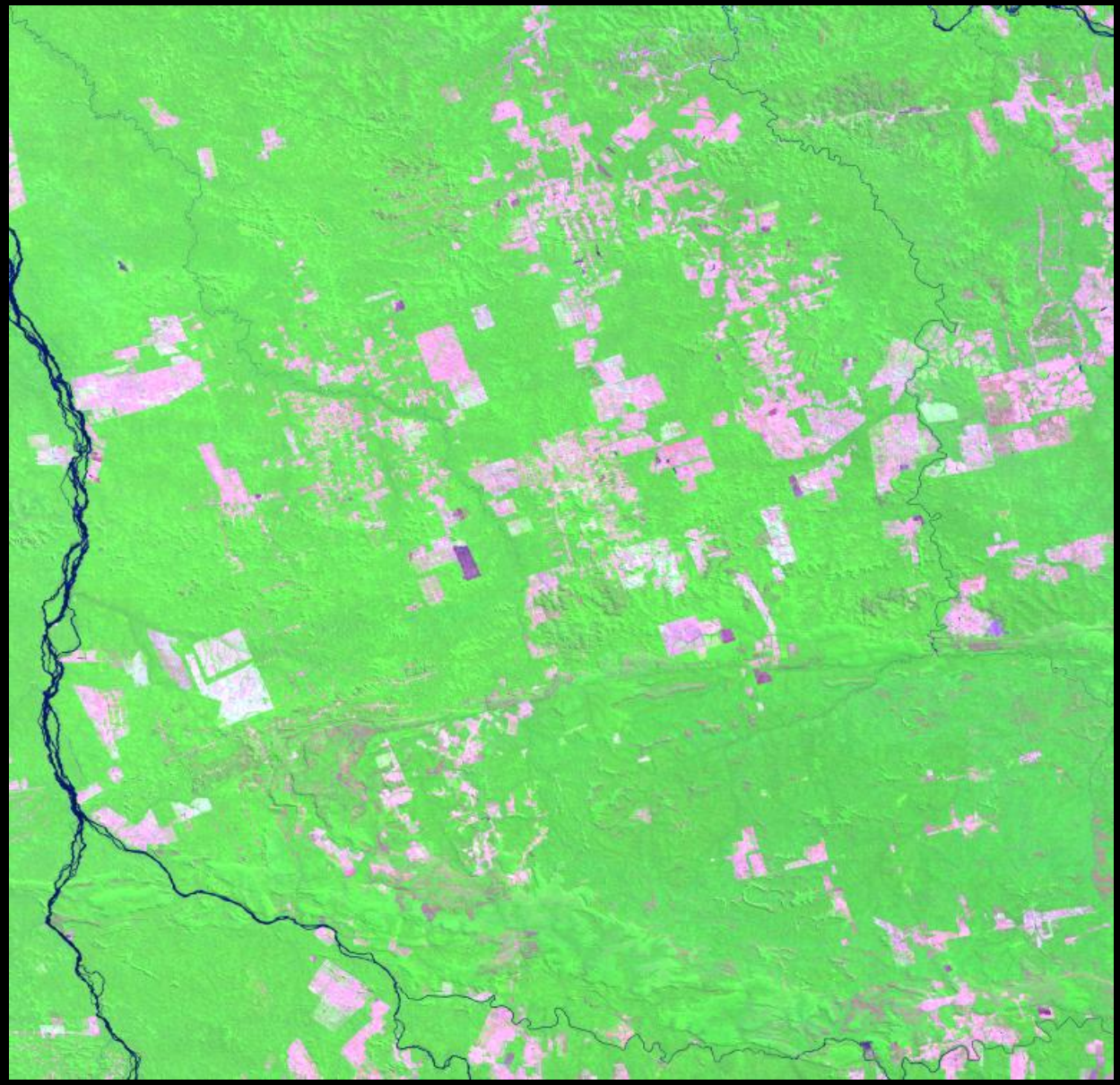
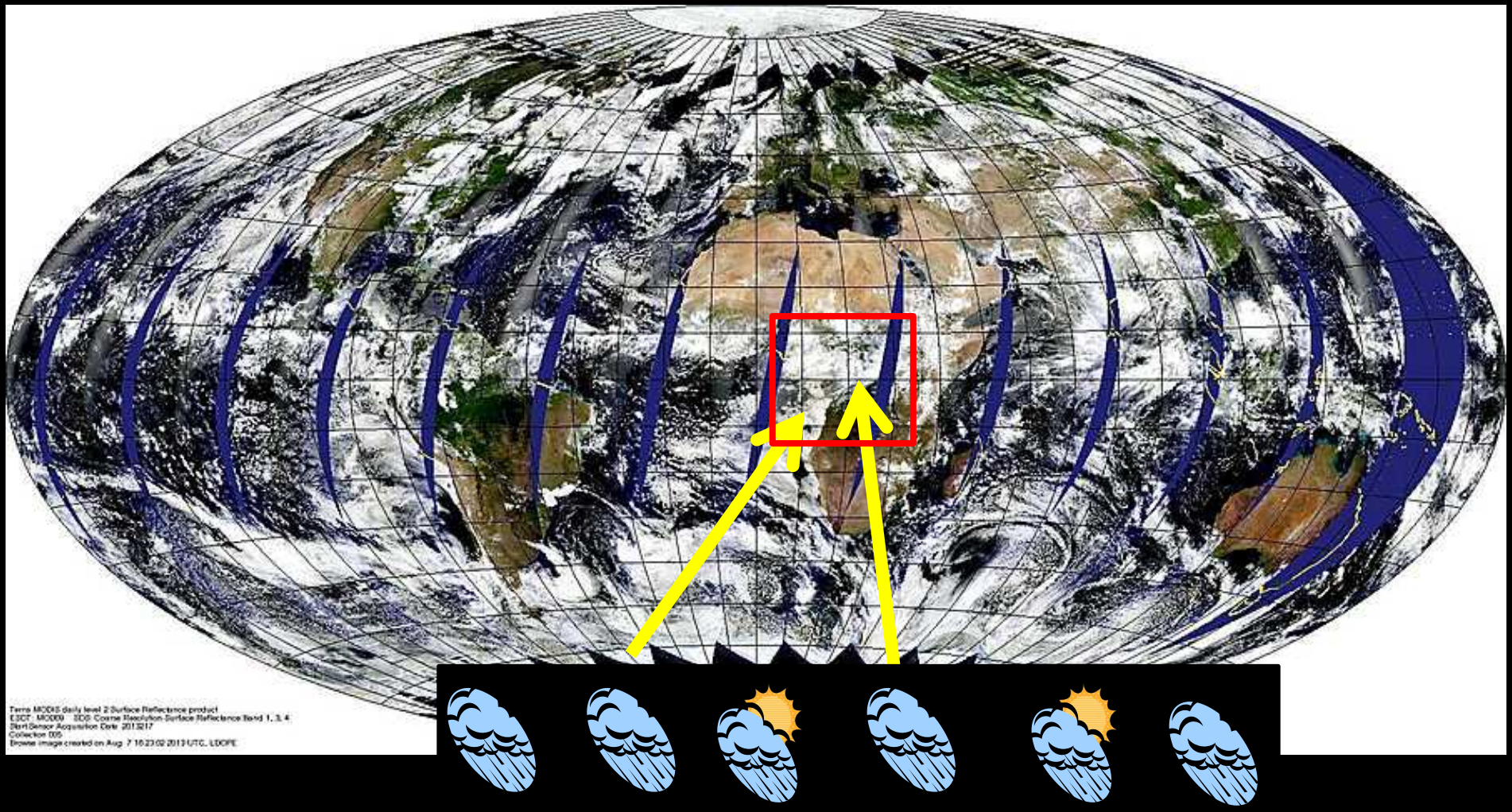
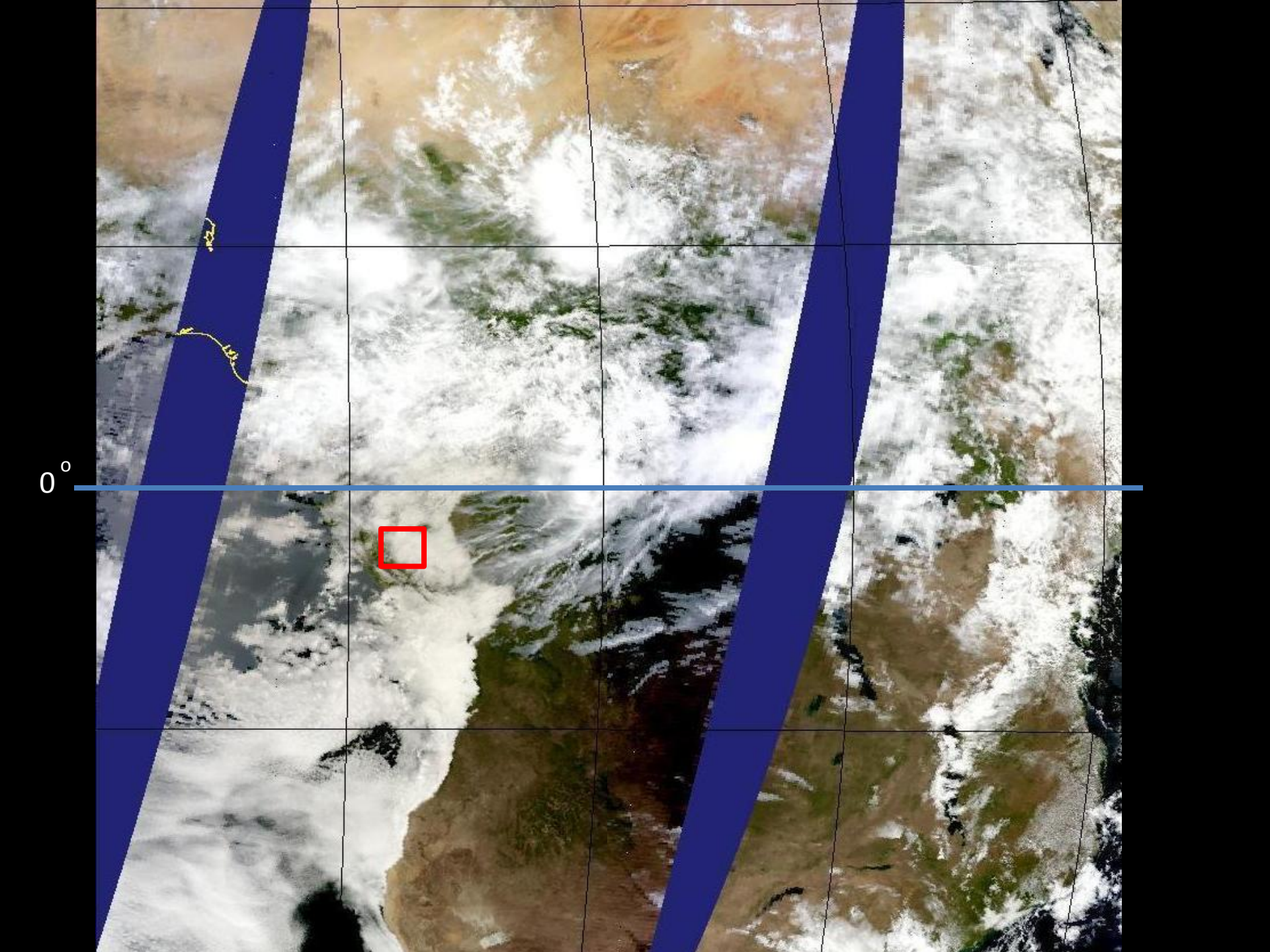


2000 day 208

Conversely, Central Africa is persistently cloudy

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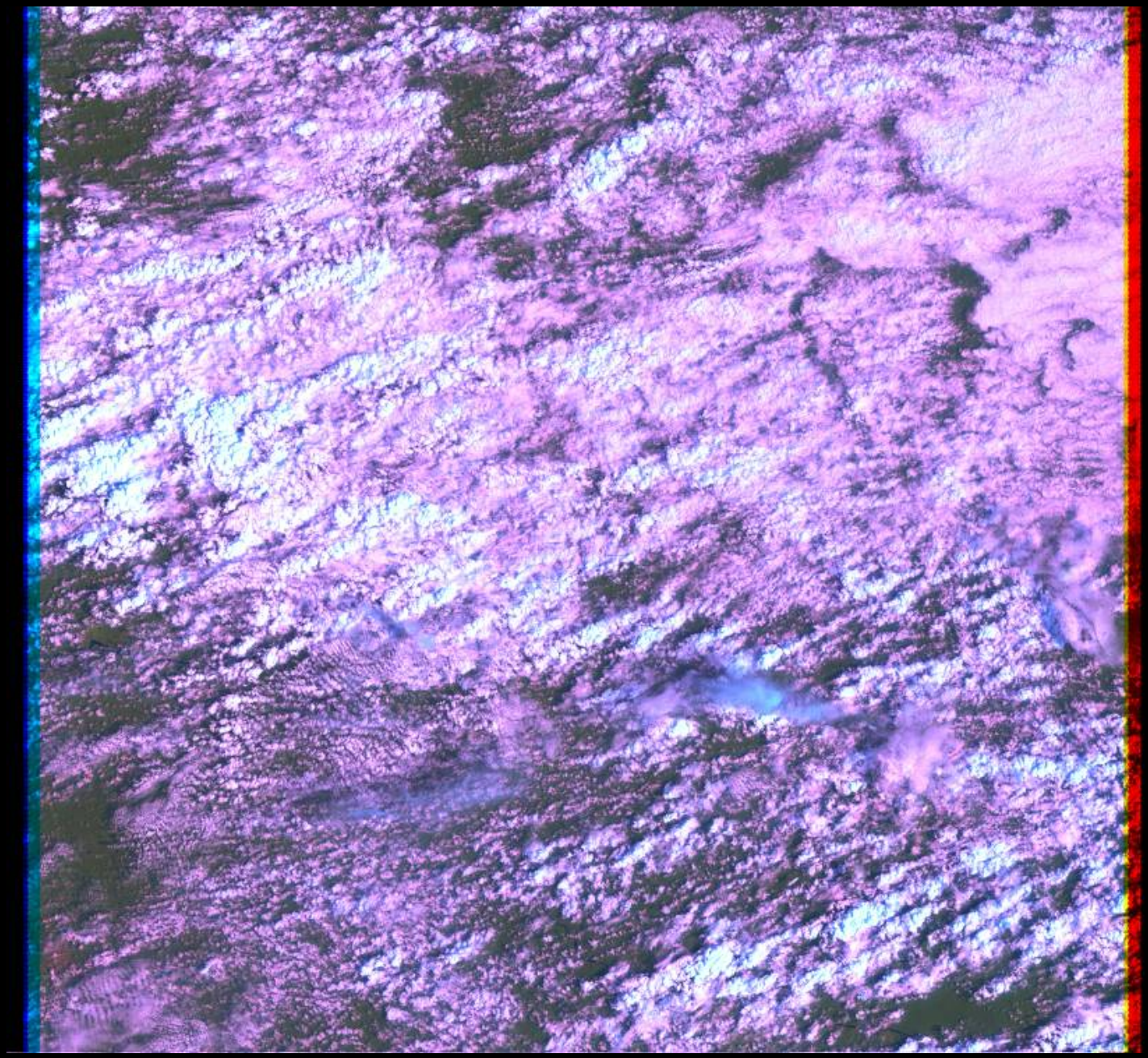

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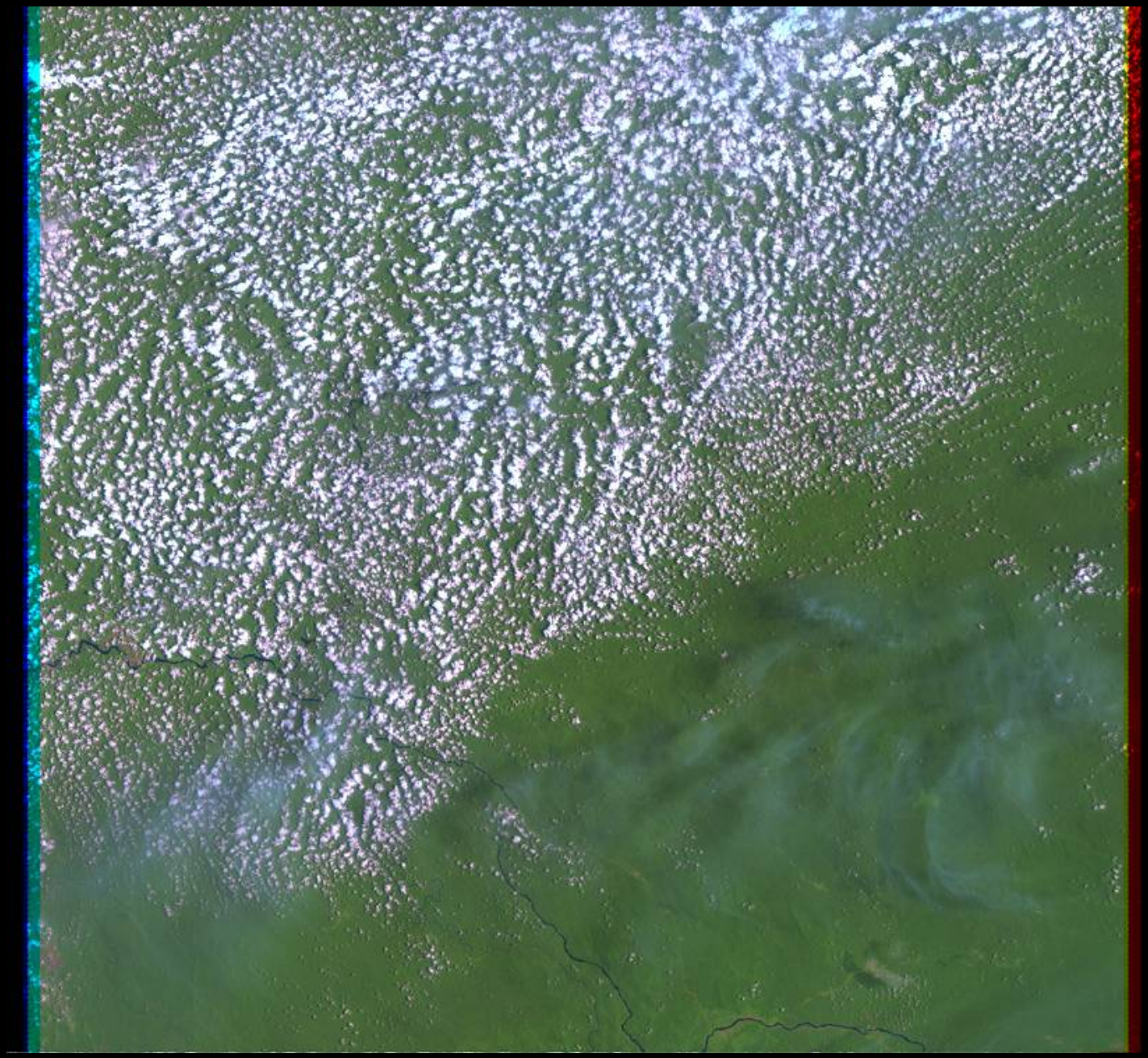

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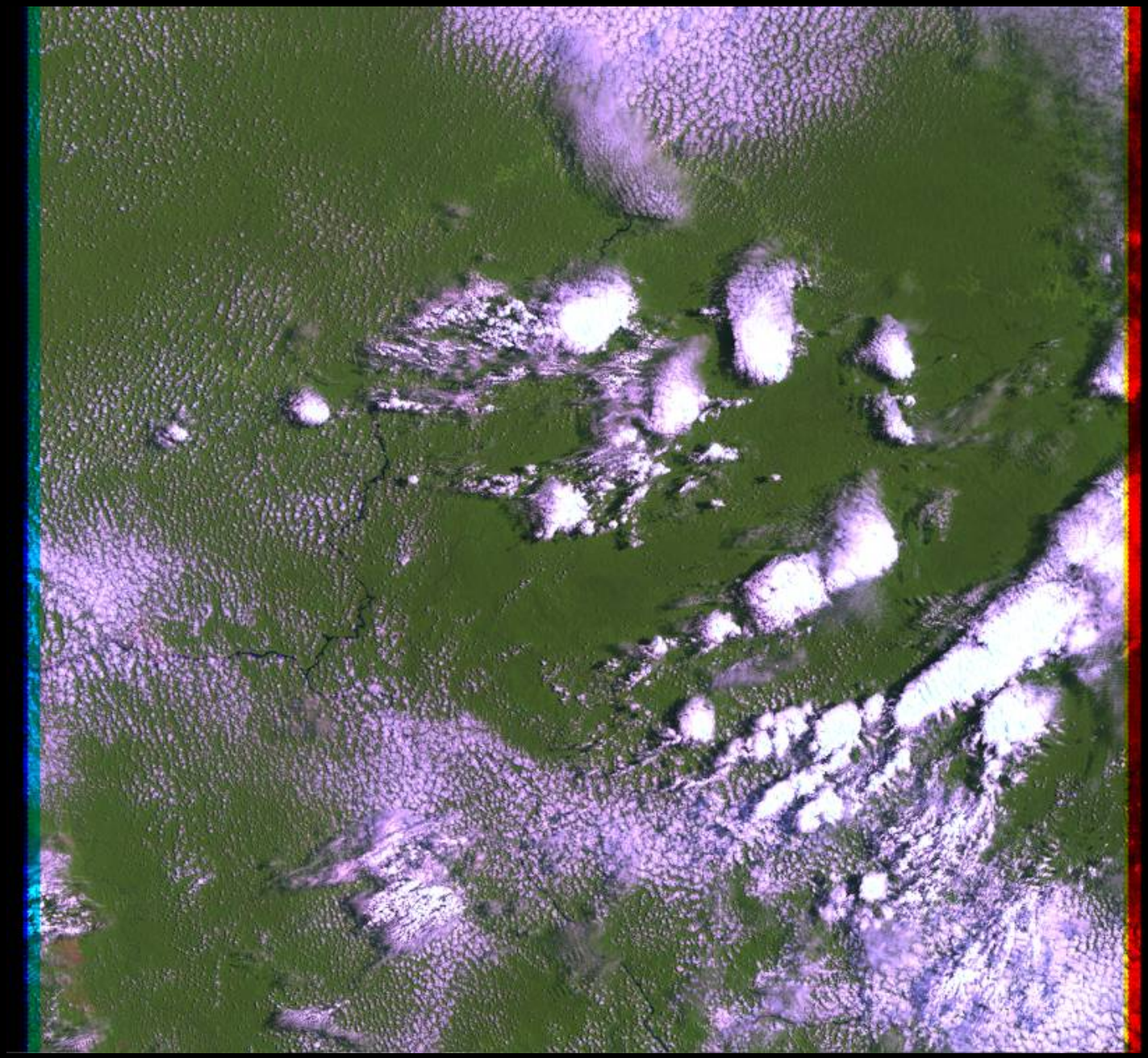

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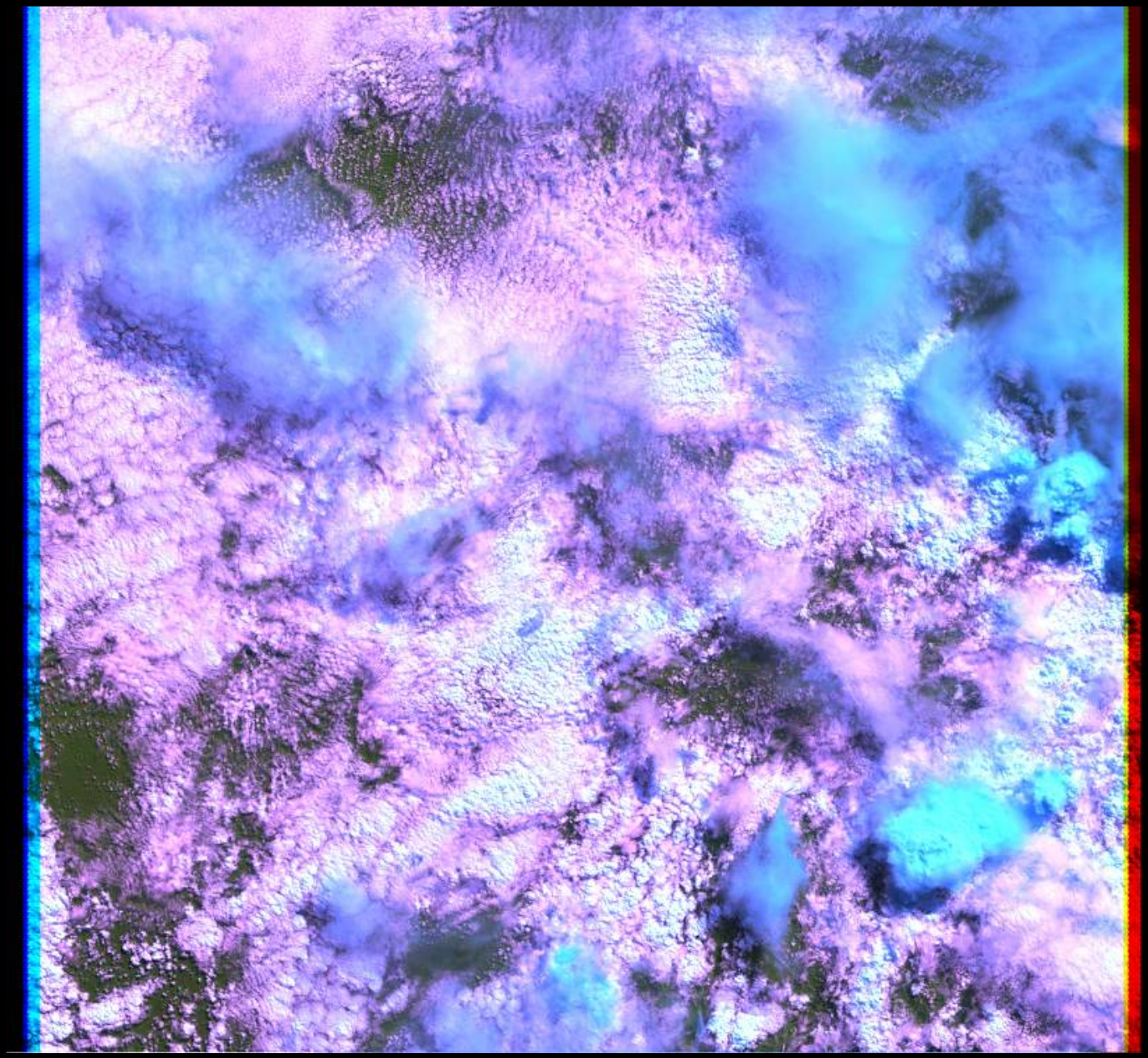

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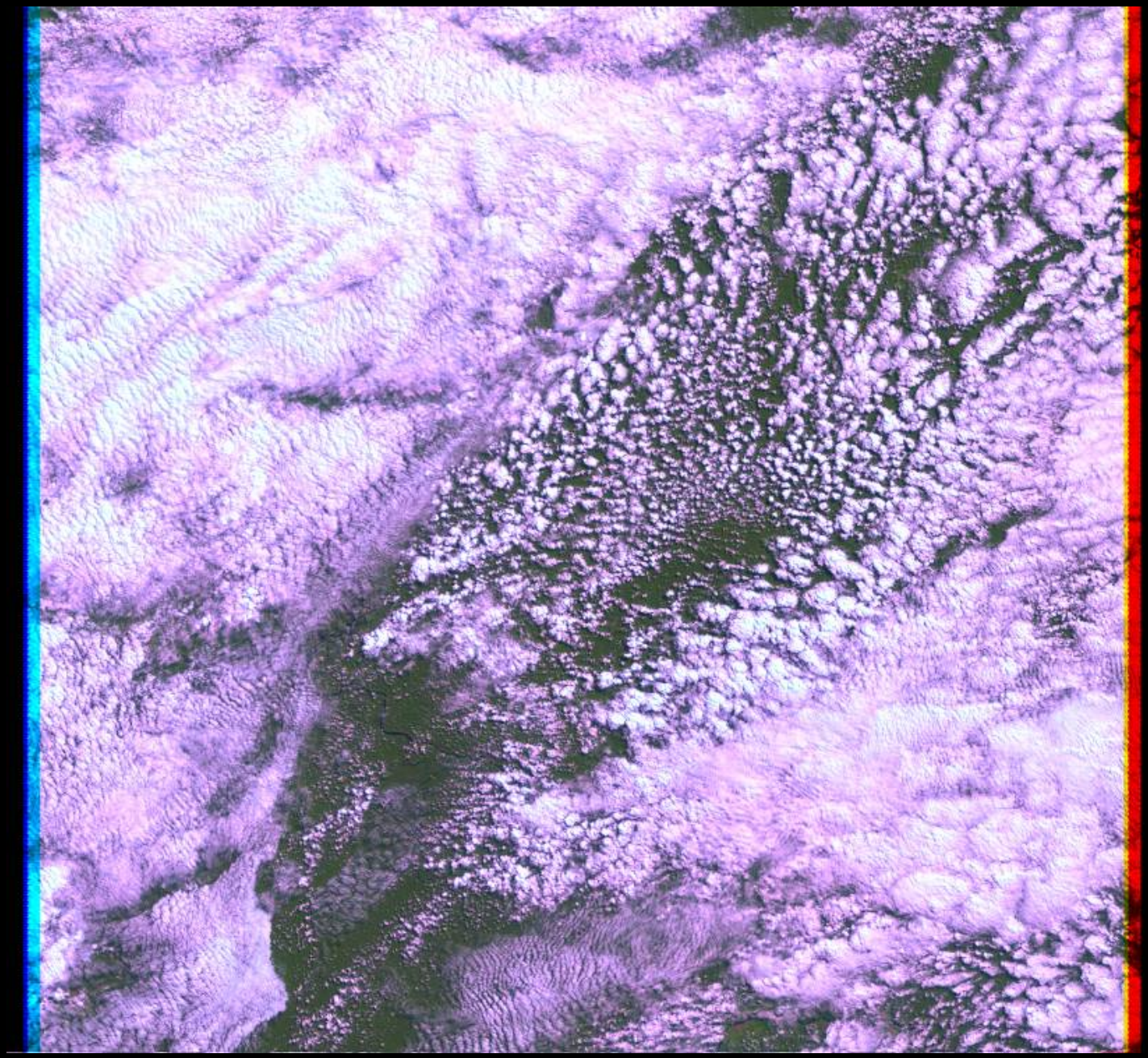

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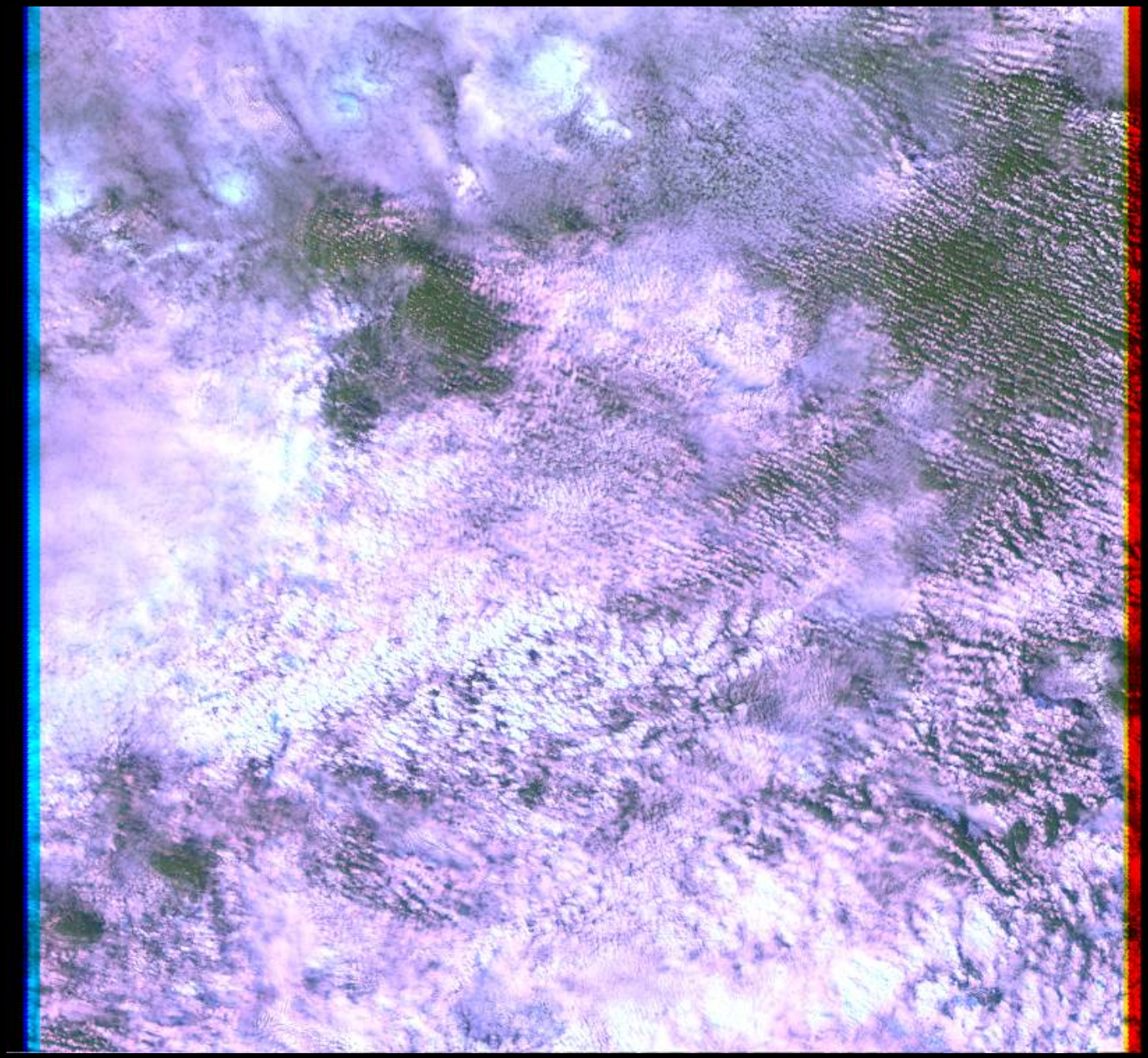

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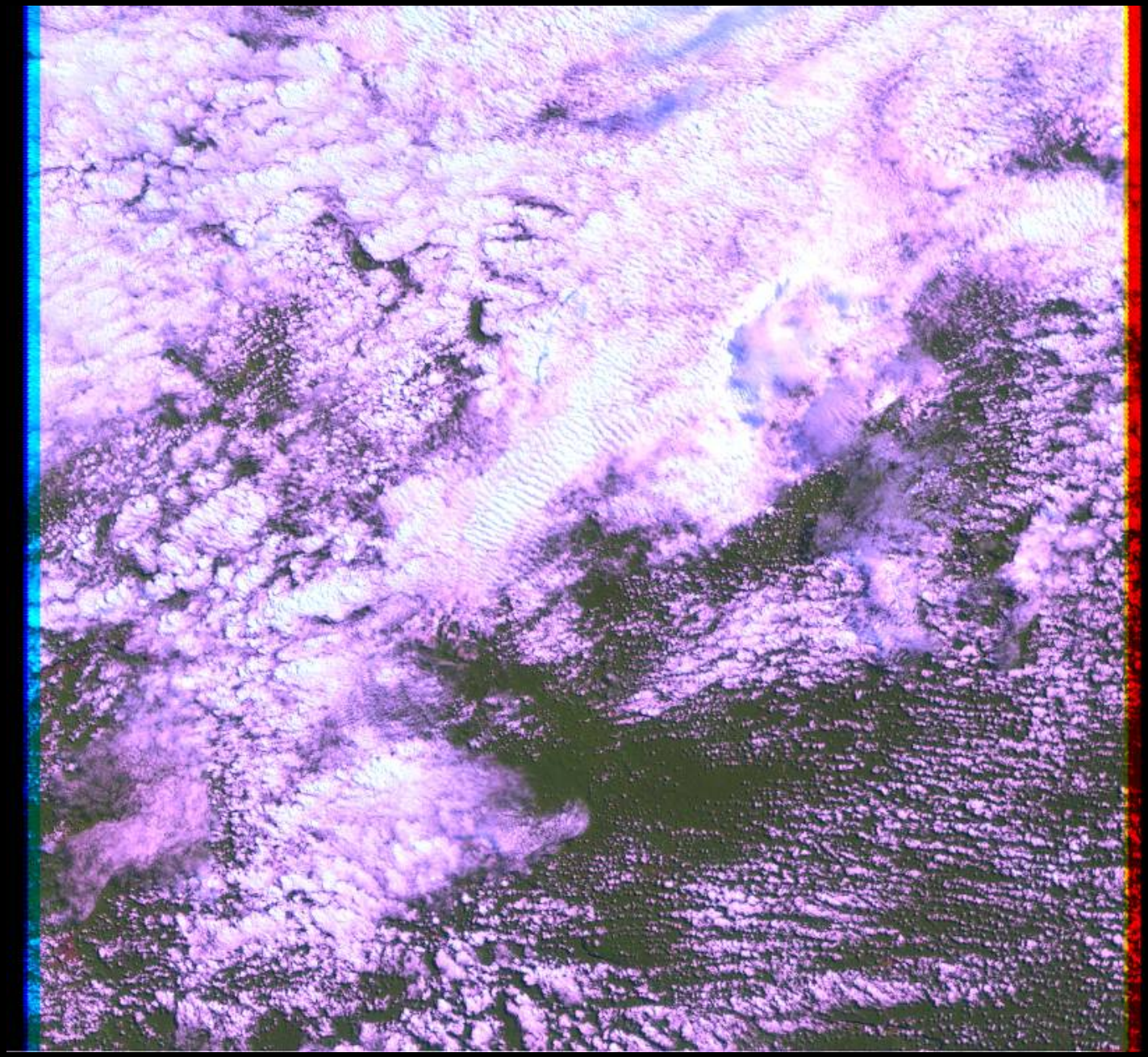

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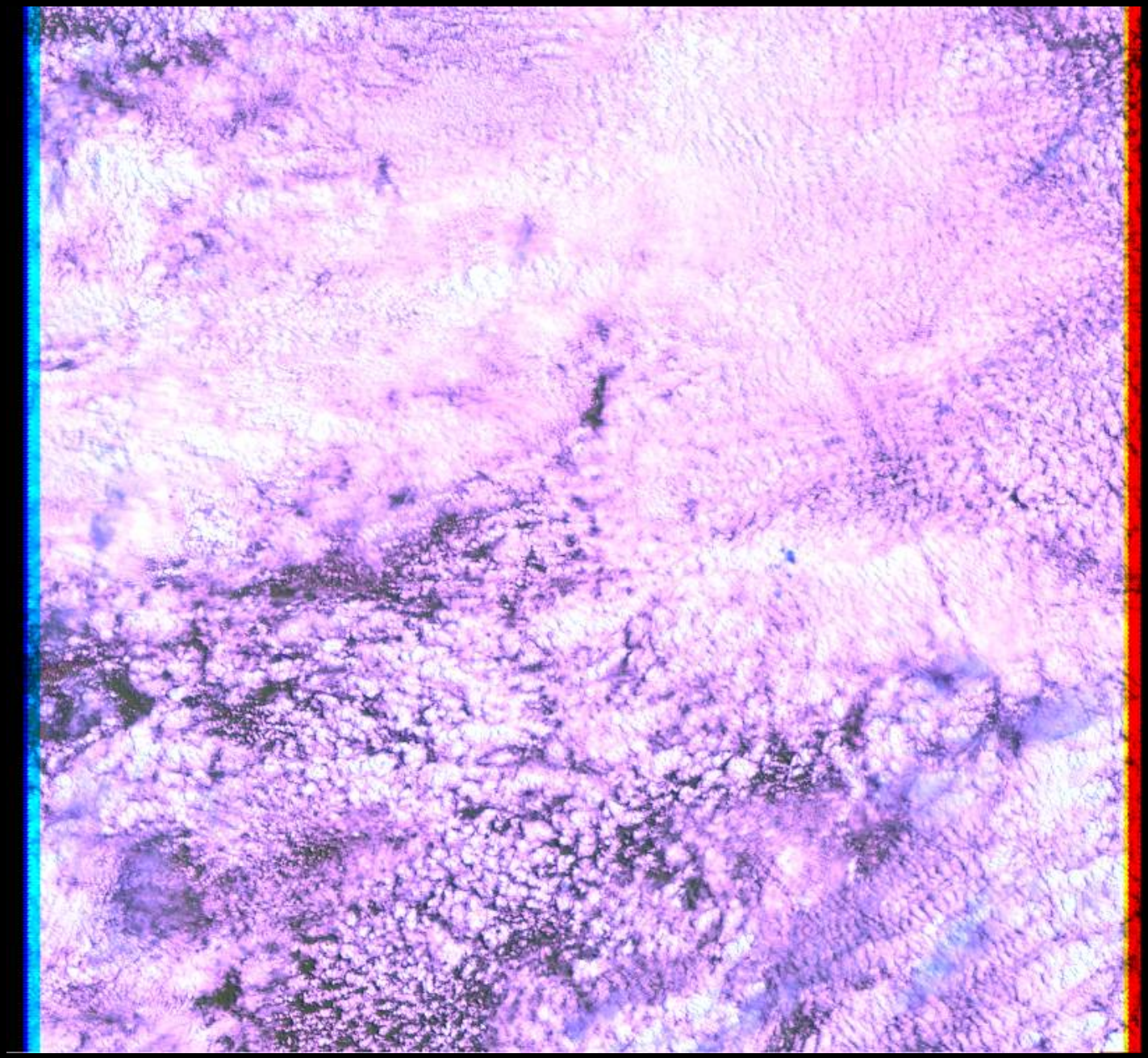

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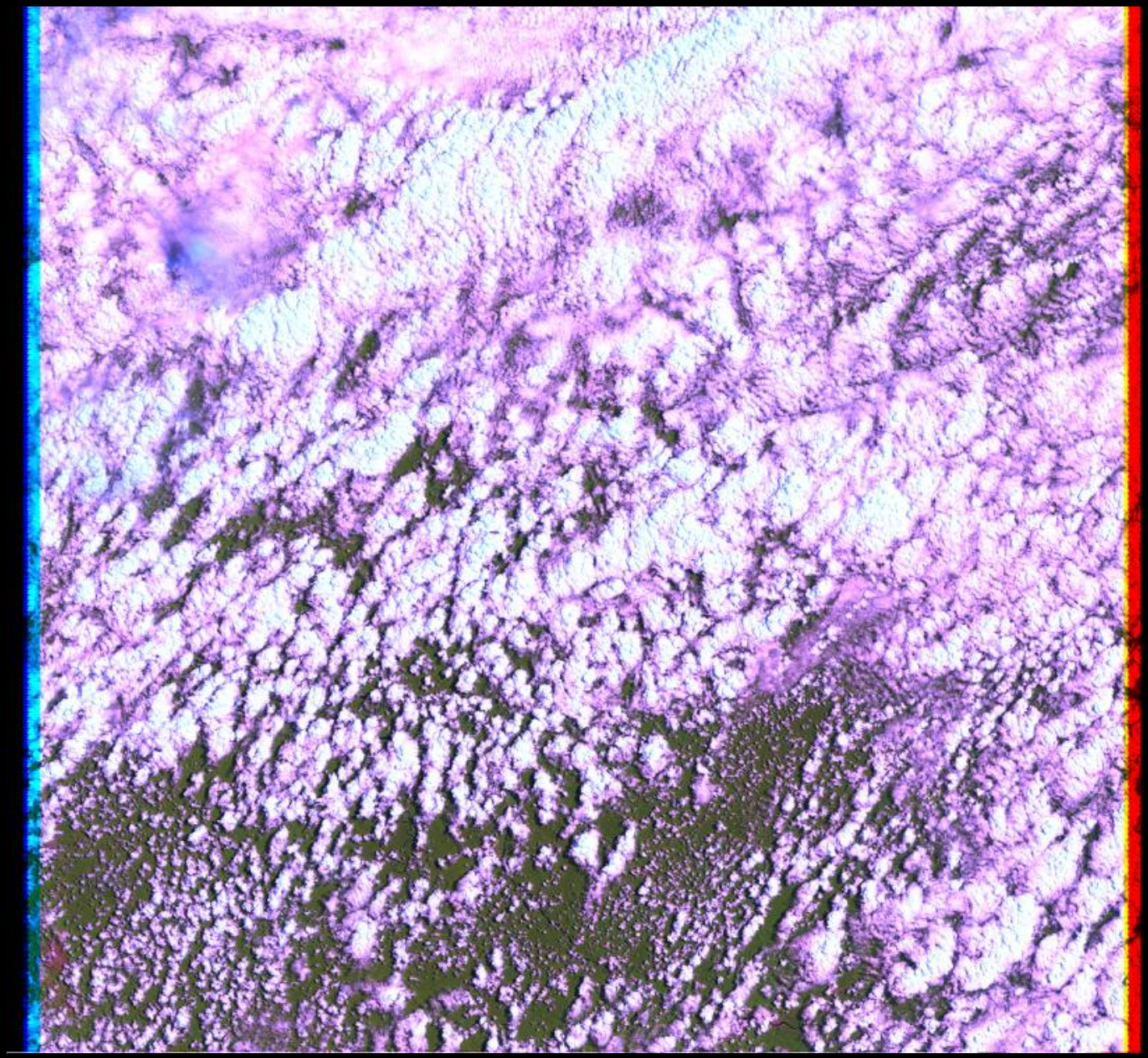

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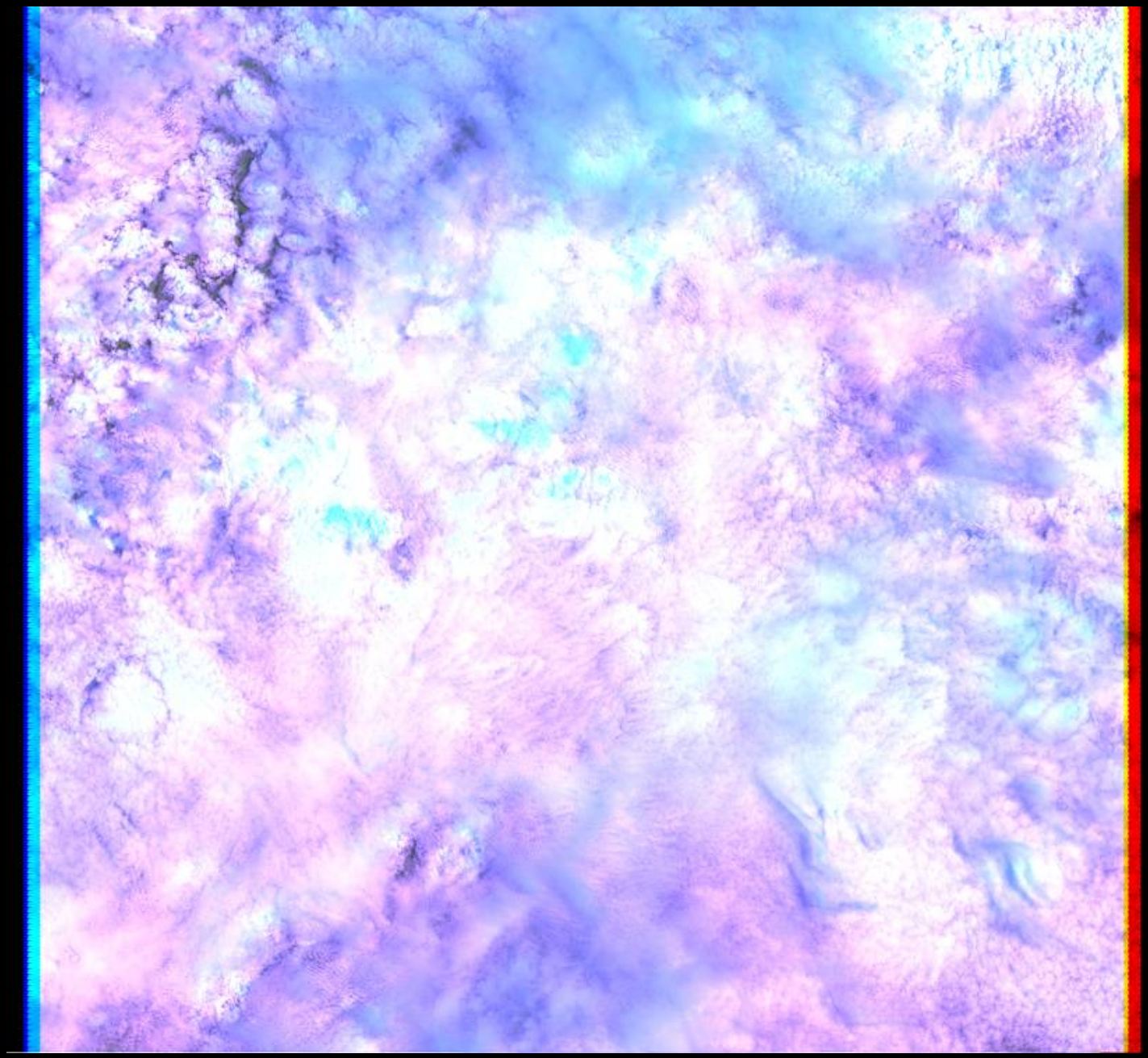

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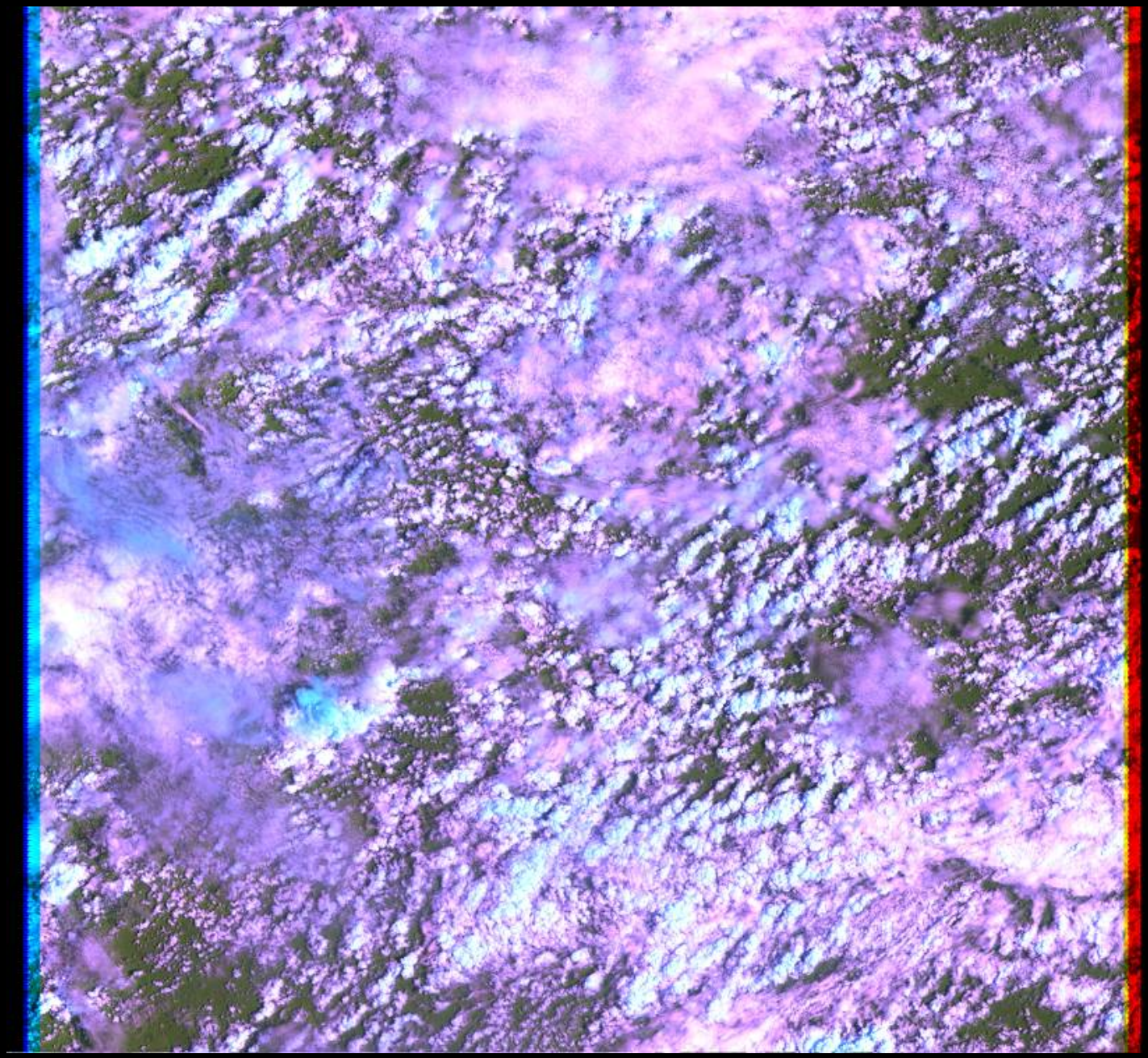

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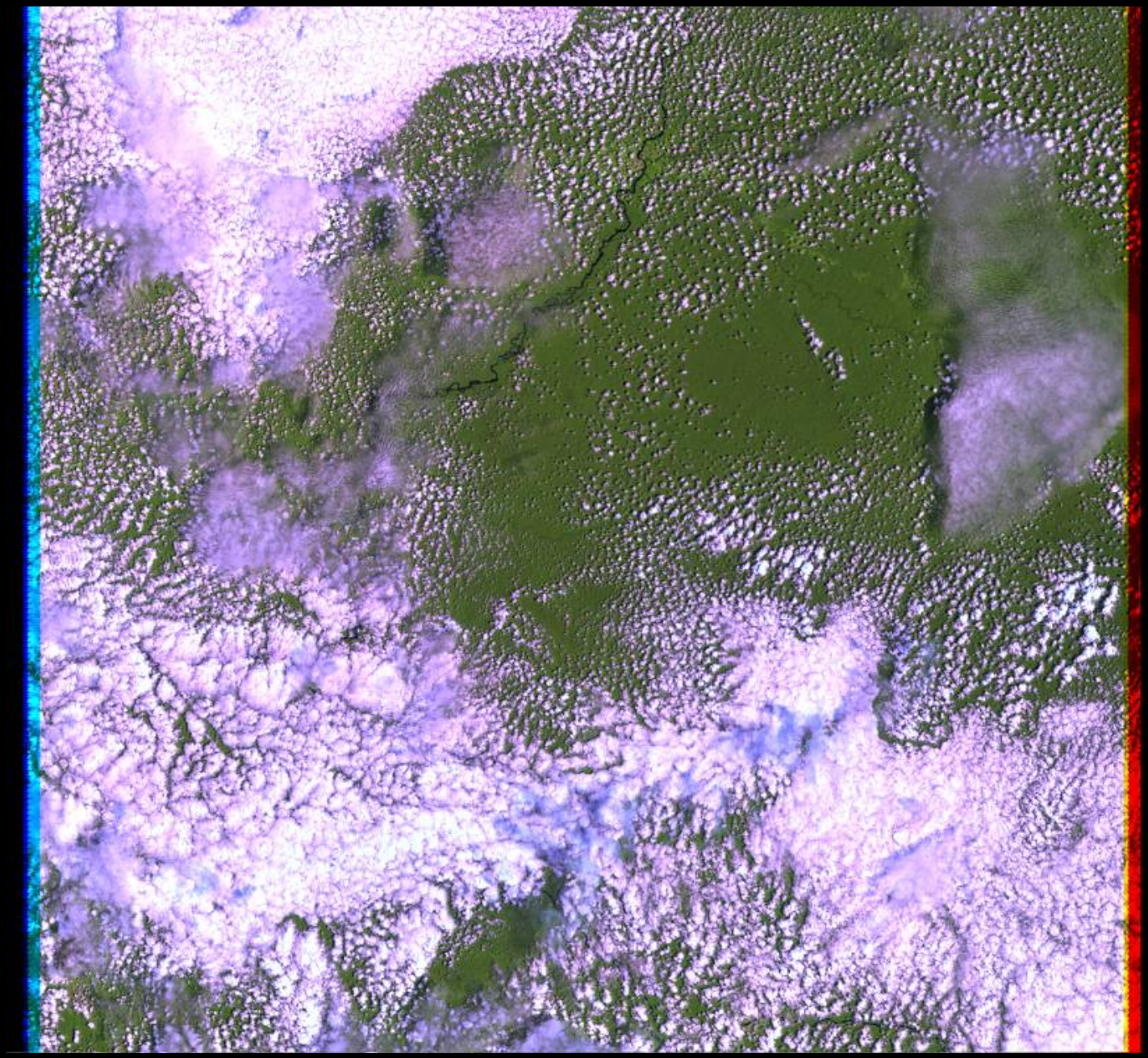

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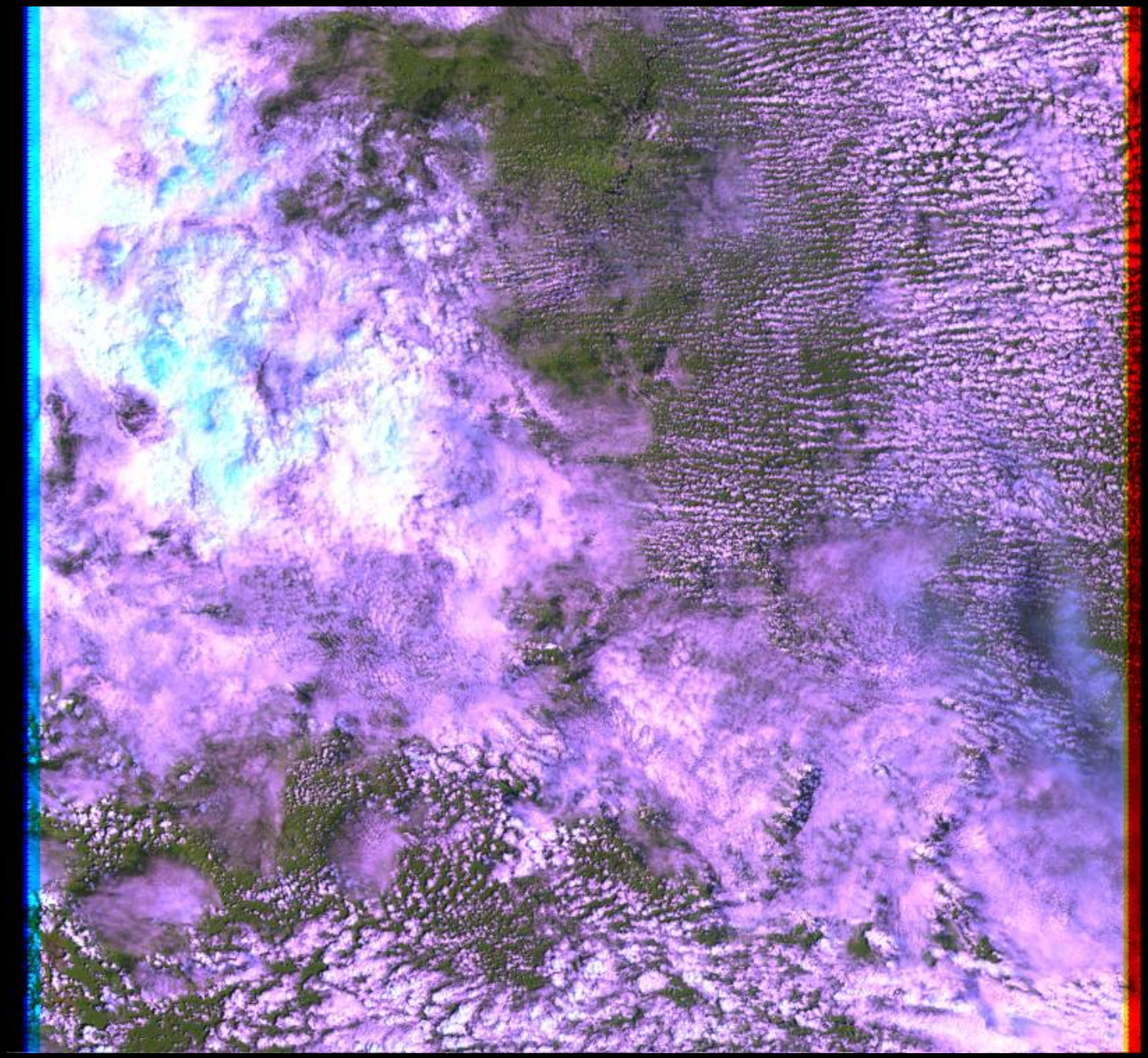

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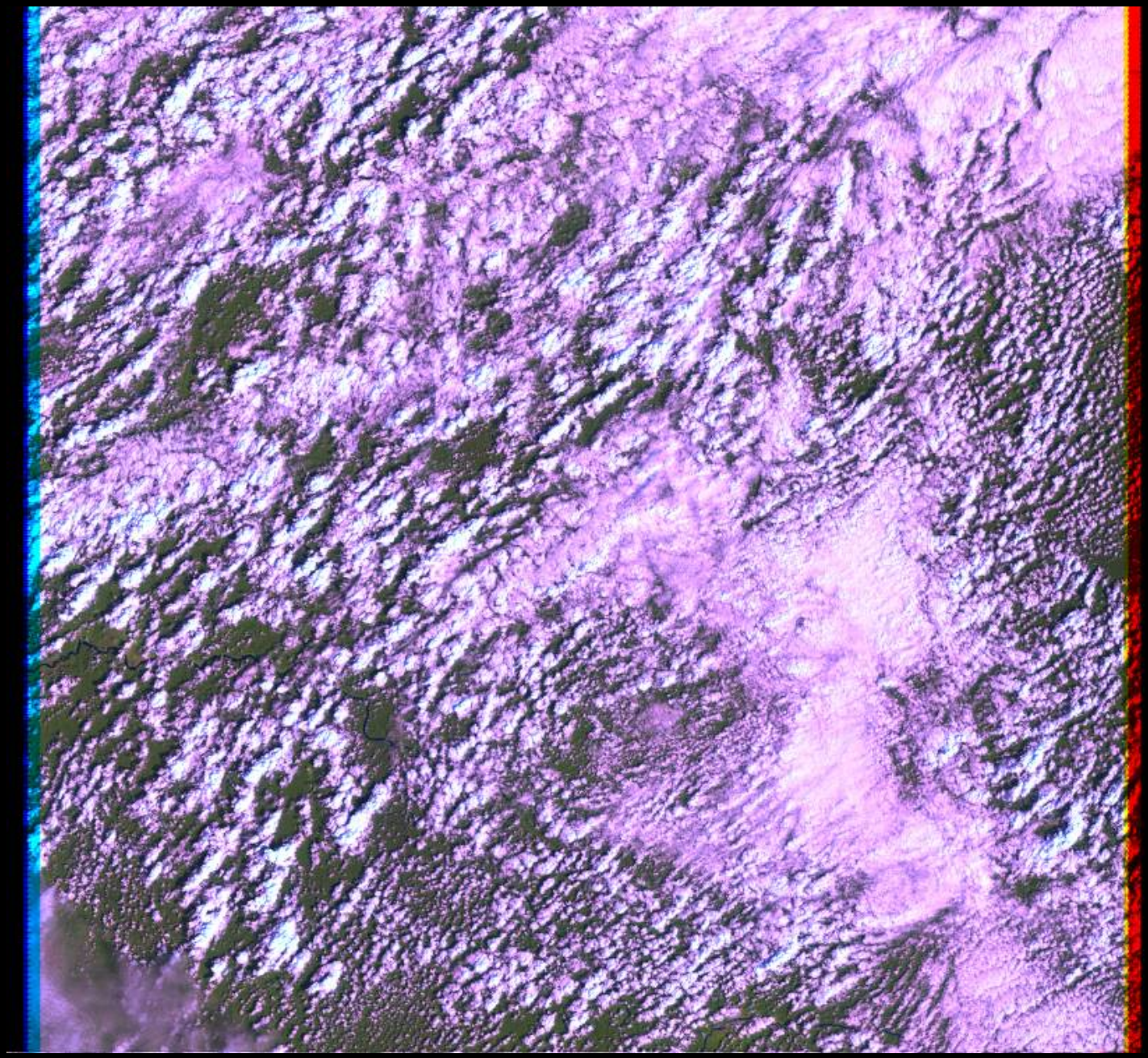
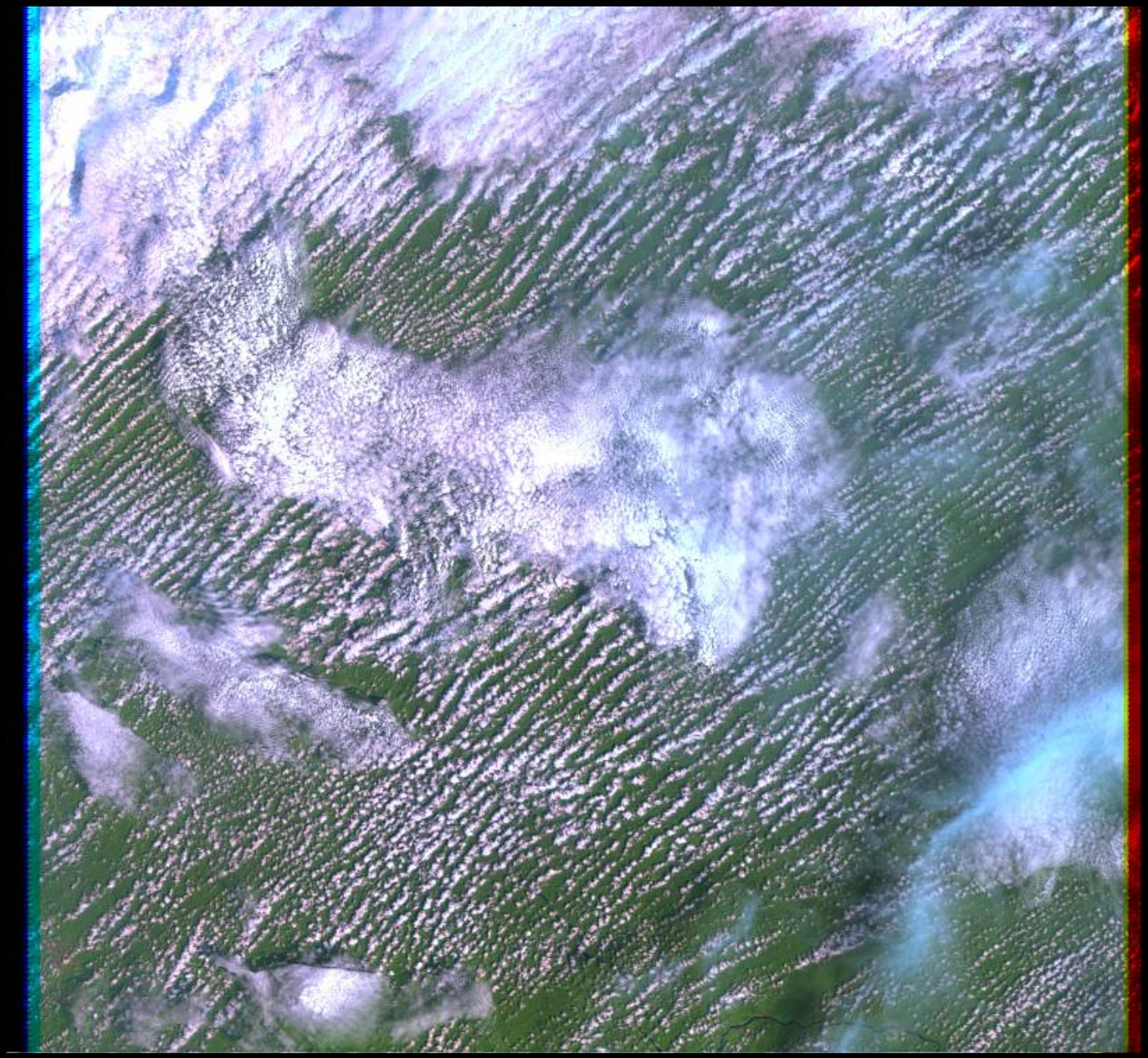


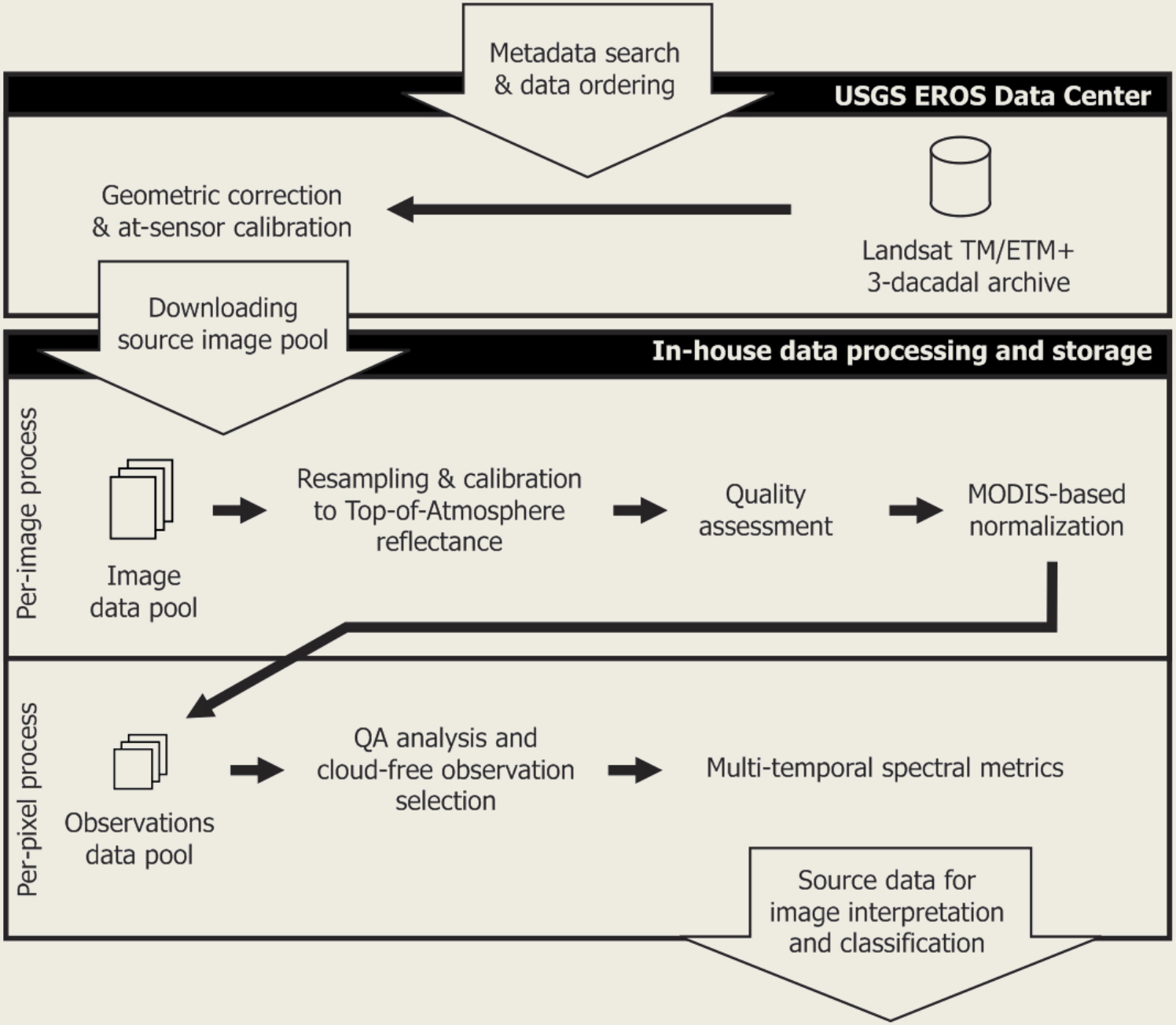
2000 day 340



2000 day 356

~2000 image composite

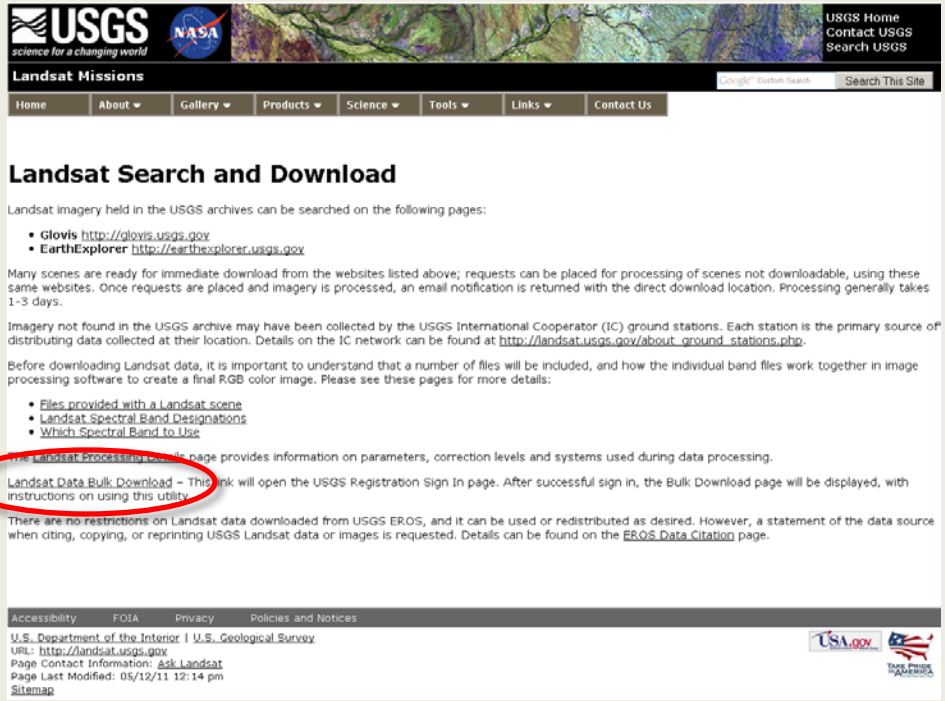
Landsat data processing workflow



Landsat data ordering and processing at the USGS EROS

1. Create WRS2 Path/Row catalog for the AOI

2. Search for relatively cloud-free scenes (70-80% max cloud cover) over selected area, time interval, and season

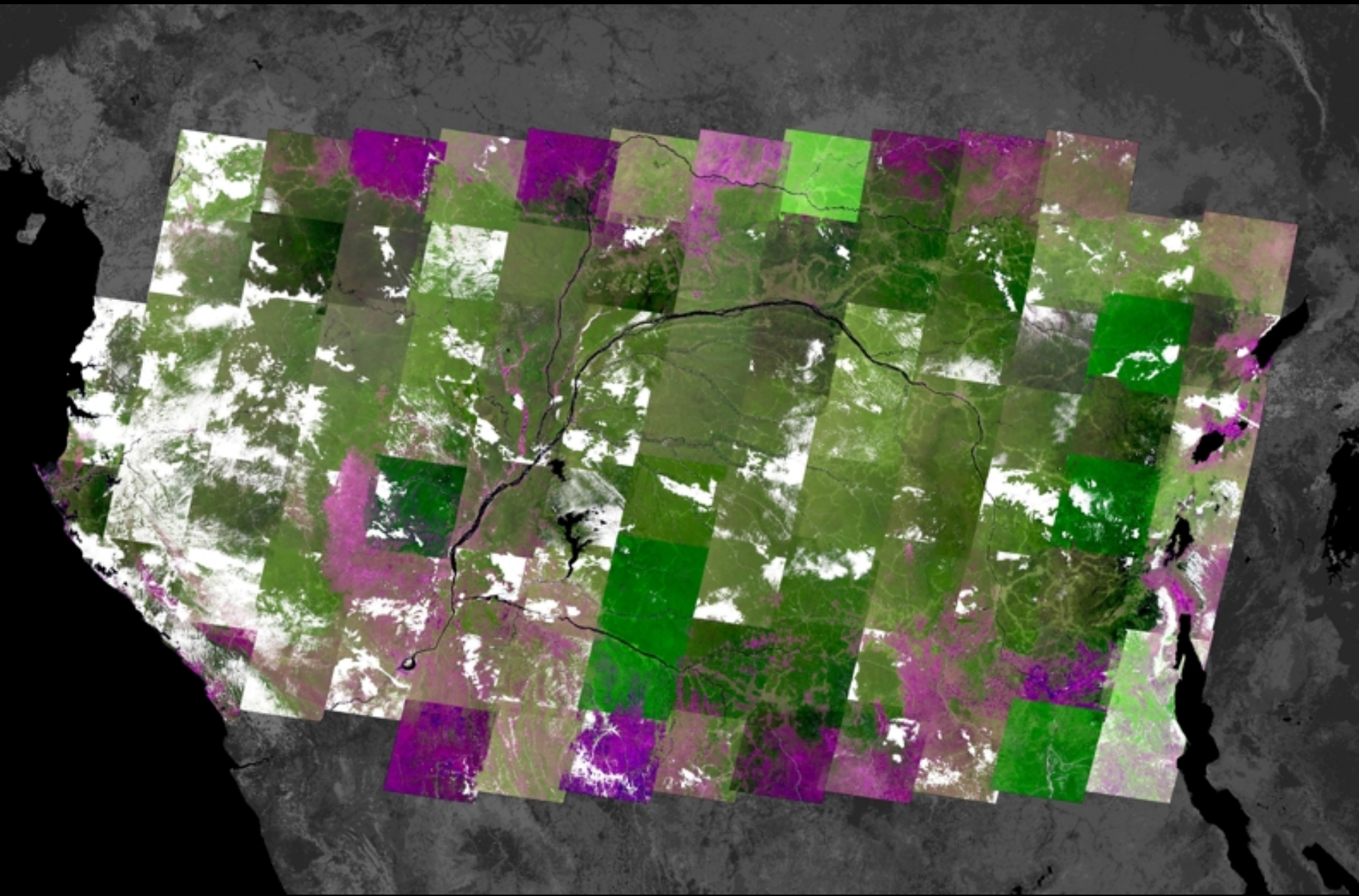


3. Order and Download data using Landsat bulk order interface

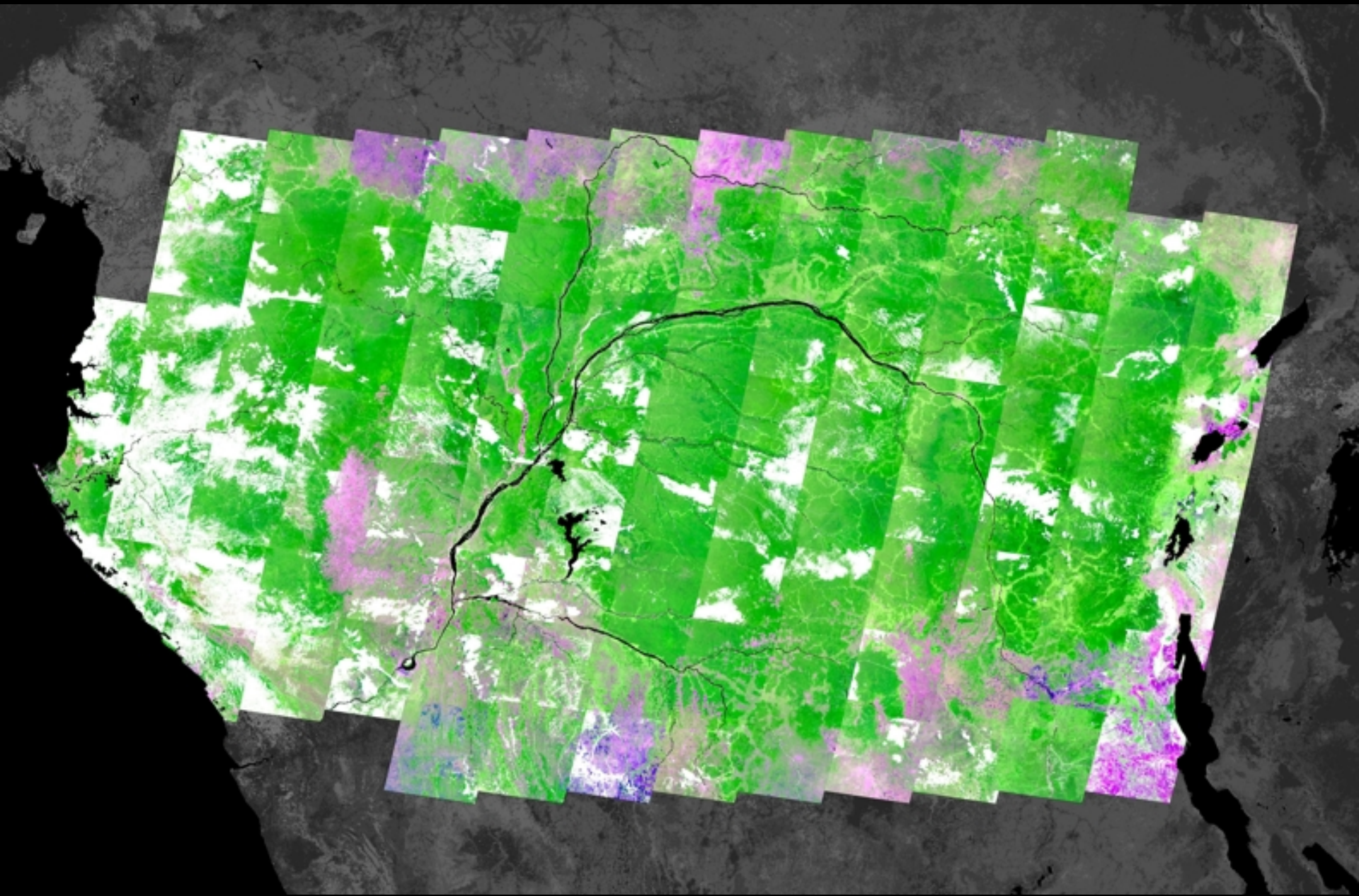
4. Check for product level (L1T vs. L1G) and GCP error statistic to filter out images with poor registration.

http://landsat.usgs.gov/Landsat_Search_and_Download.php

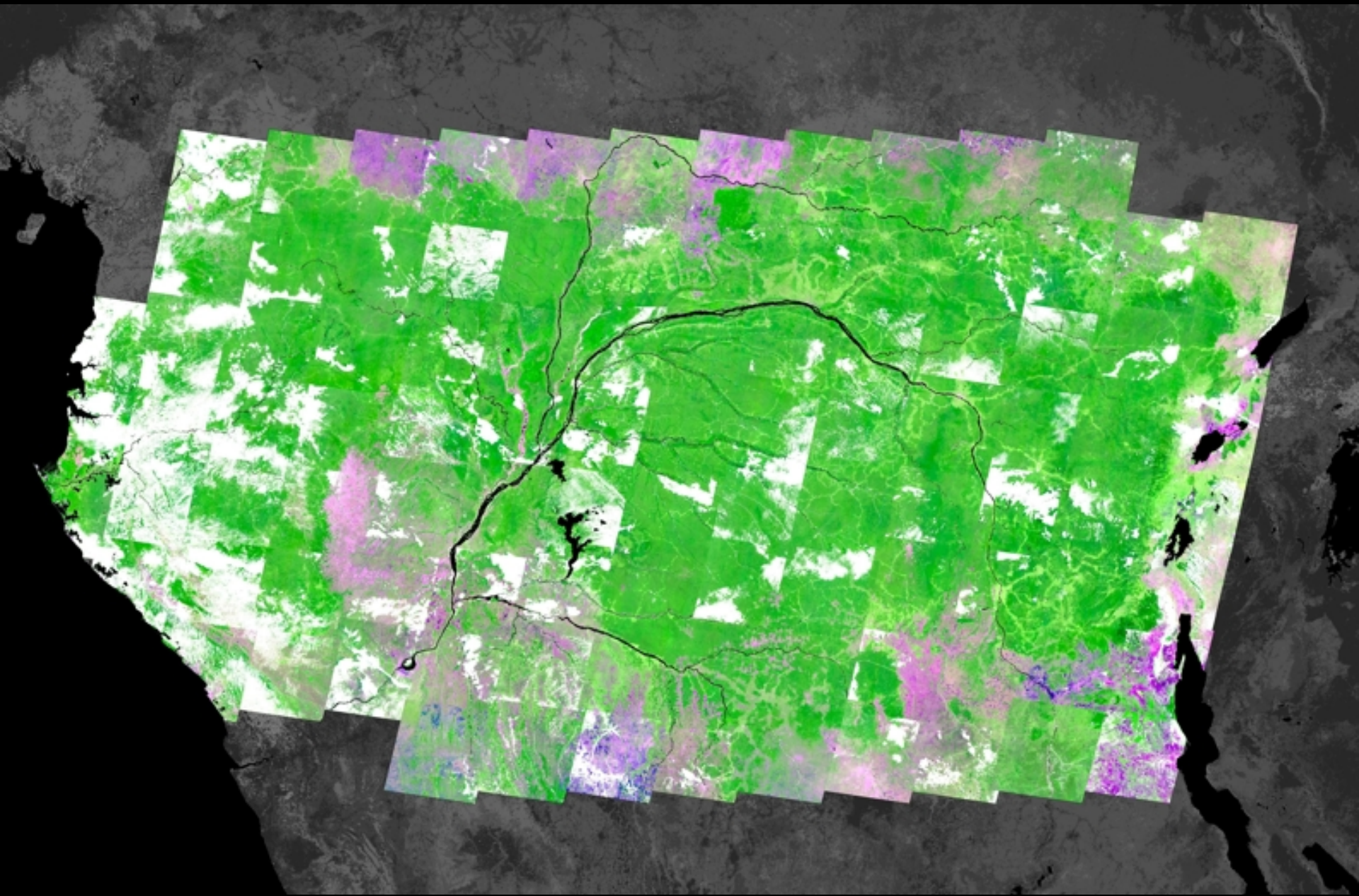
Uncorrected imagery



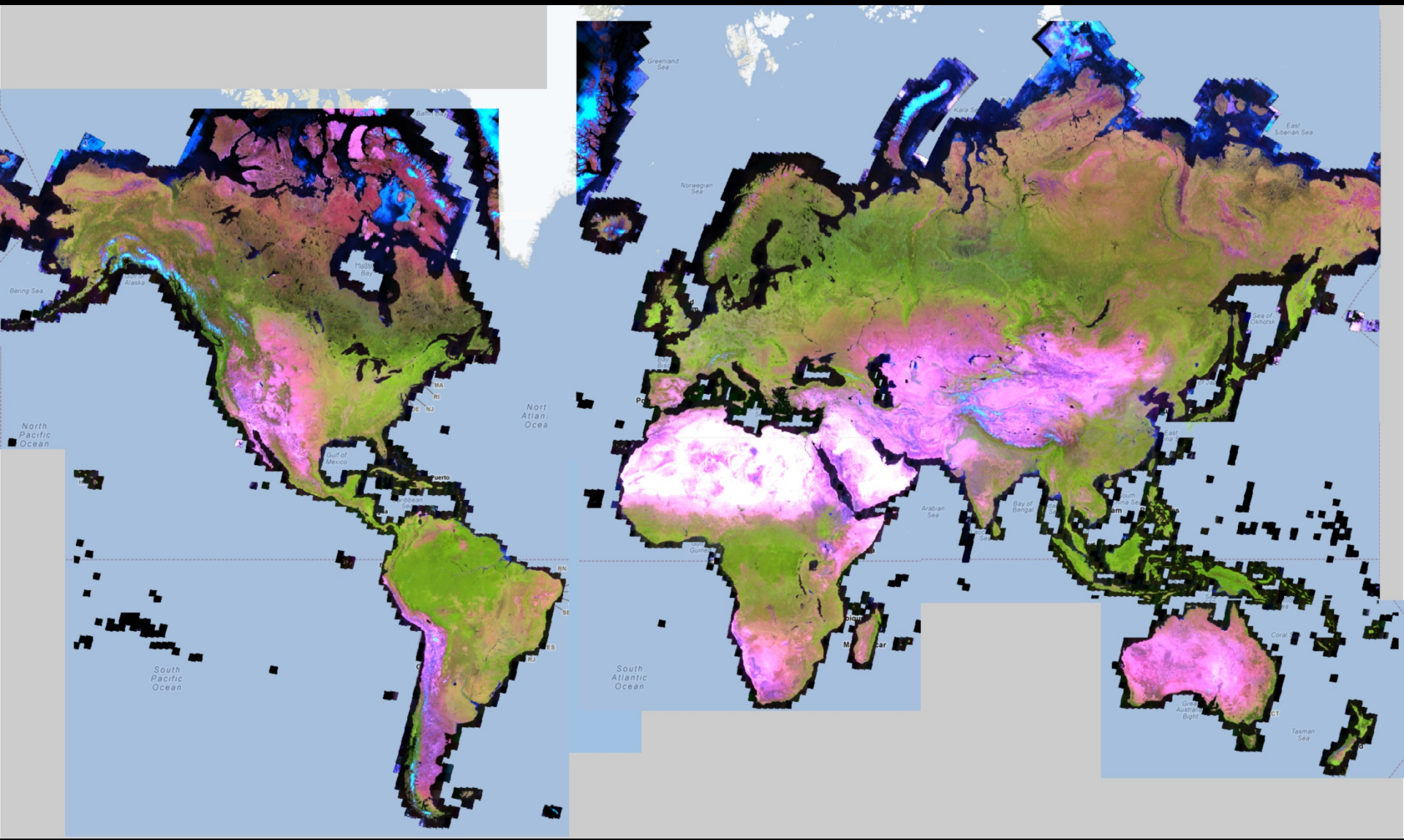
Bias-adjusted TOA



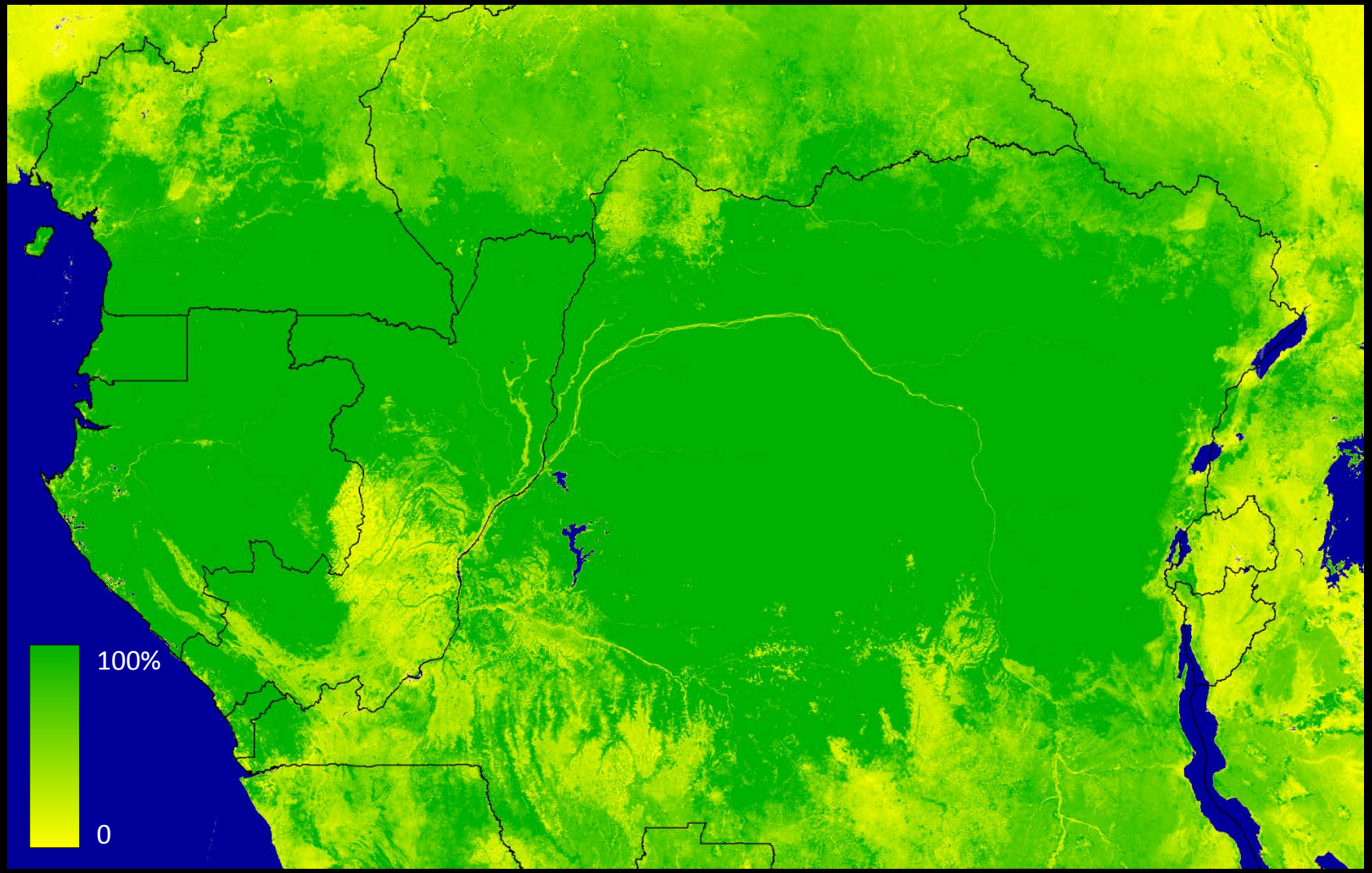
Anisotropy-adjusted



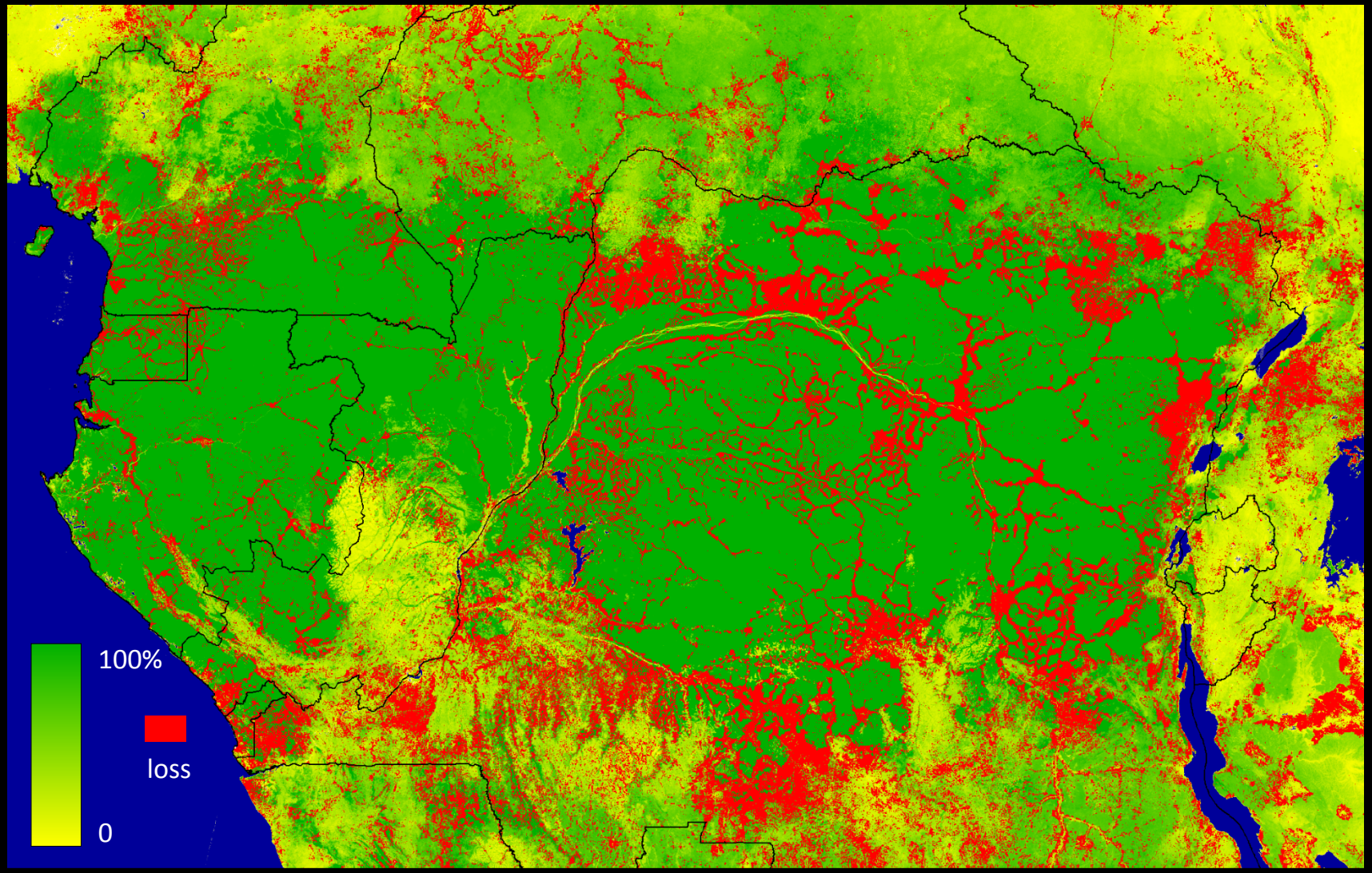
Landsat


Greenland Sea
Norwegian Sea
East Siberian Sea
Bering Sea
North Pacific Ocean
Nort Atlan Ocea
Gulf of Mexico
Arabian Sea
Bay of Bengal
South Pacific Ocean
South Atlantic Ocean
Tasman Sea

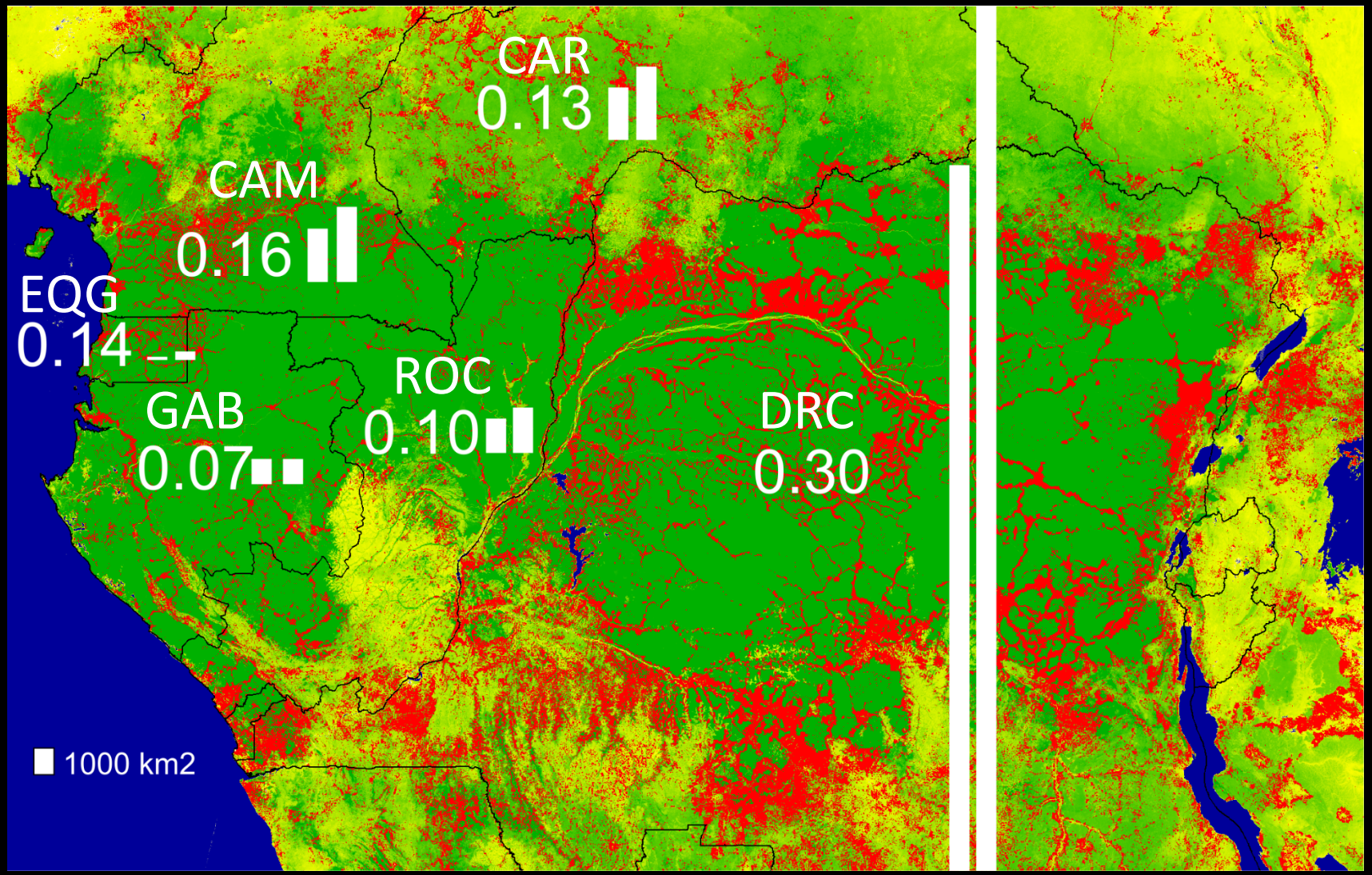
Central Africa tree cover, 2000



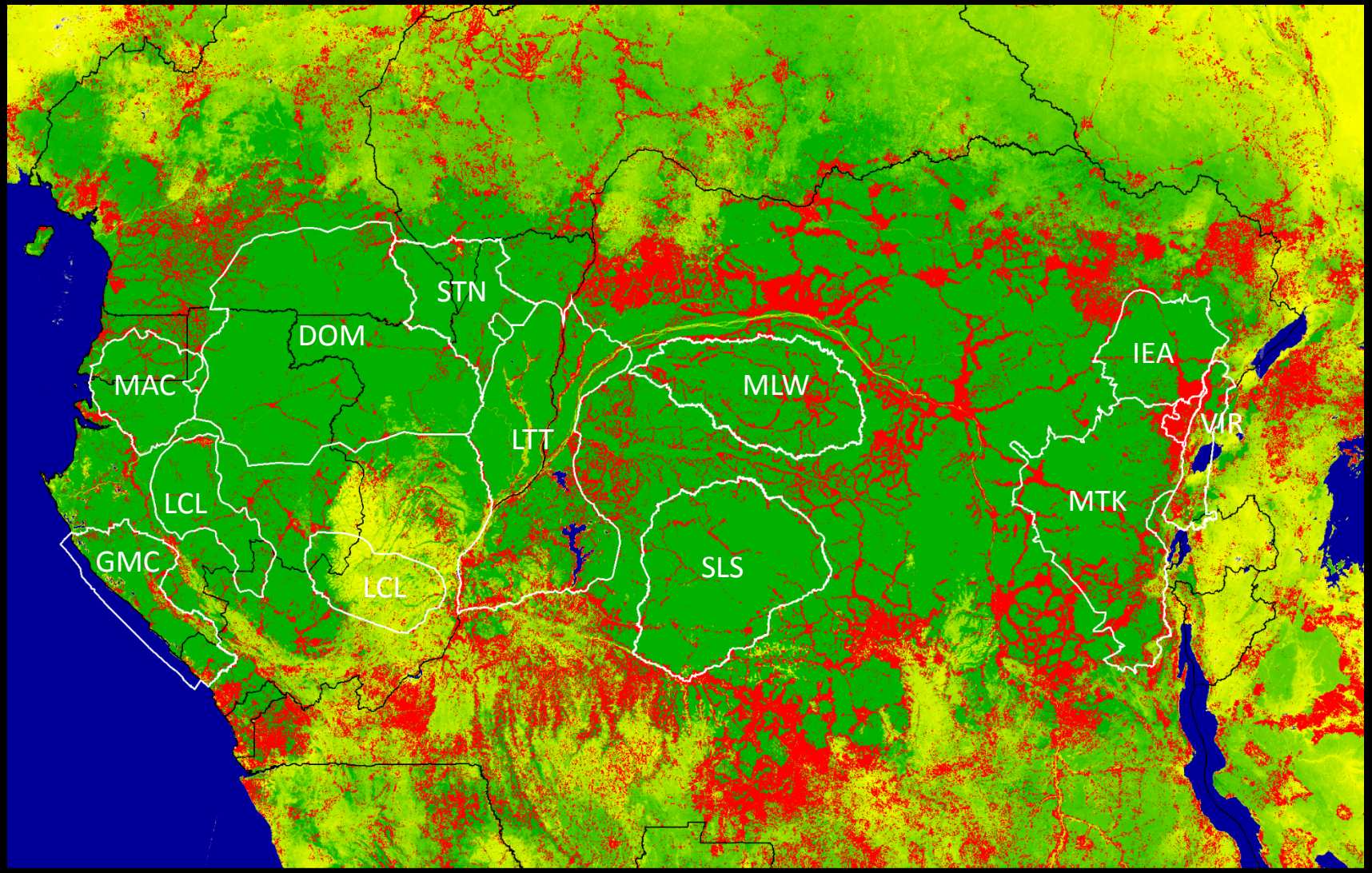
Central Africa tree cover, 2000
with forest cover loss, 2000-2012



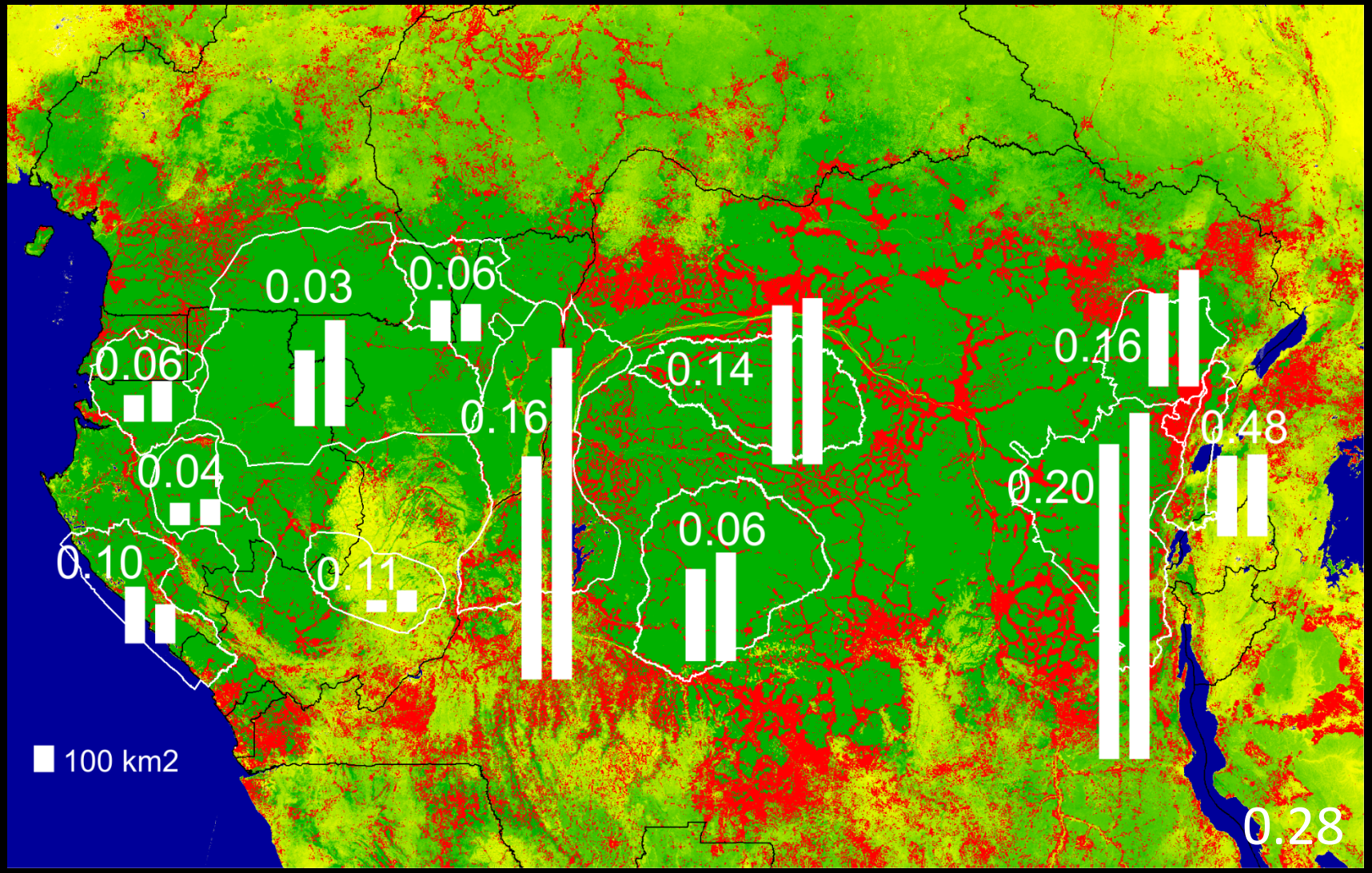
Annual percent forest cover loss, 2000-2012 and total forest loss 2000-2006 and 2006-2012

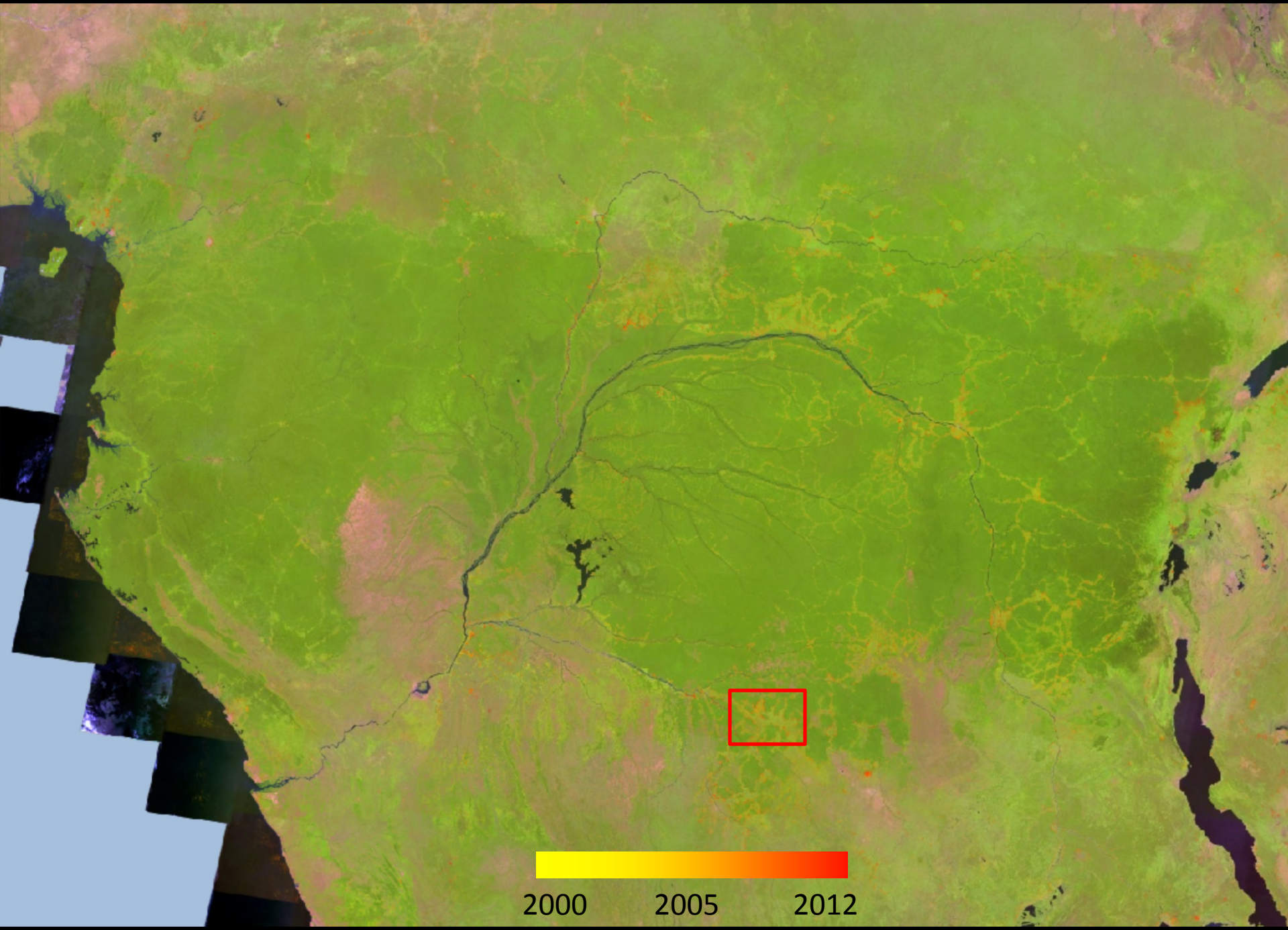


CARPE Landscapes

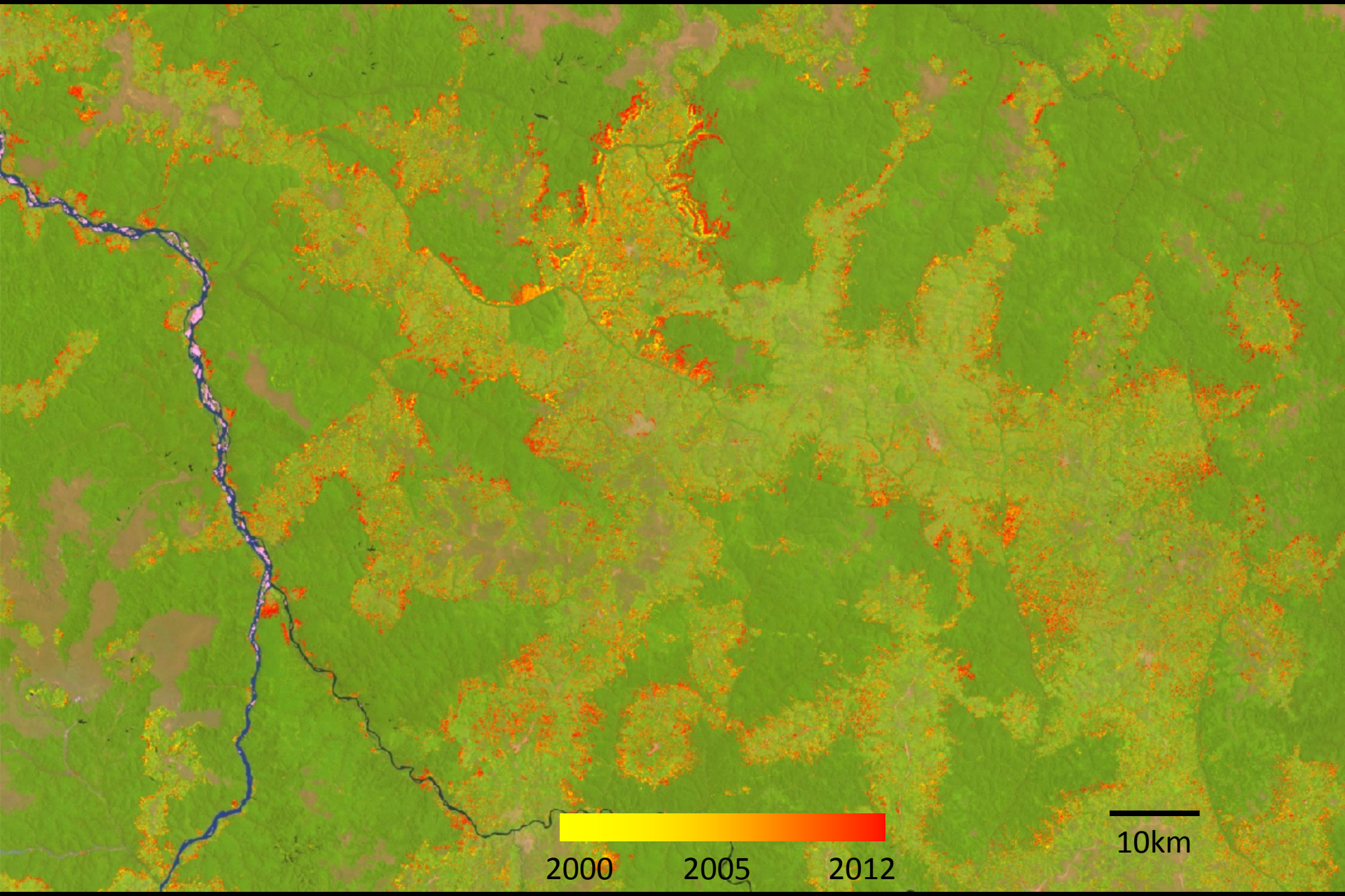


Annual percent forest cover loss, 2000-2012 and total forest loss 2000-2006 and 2006-2012

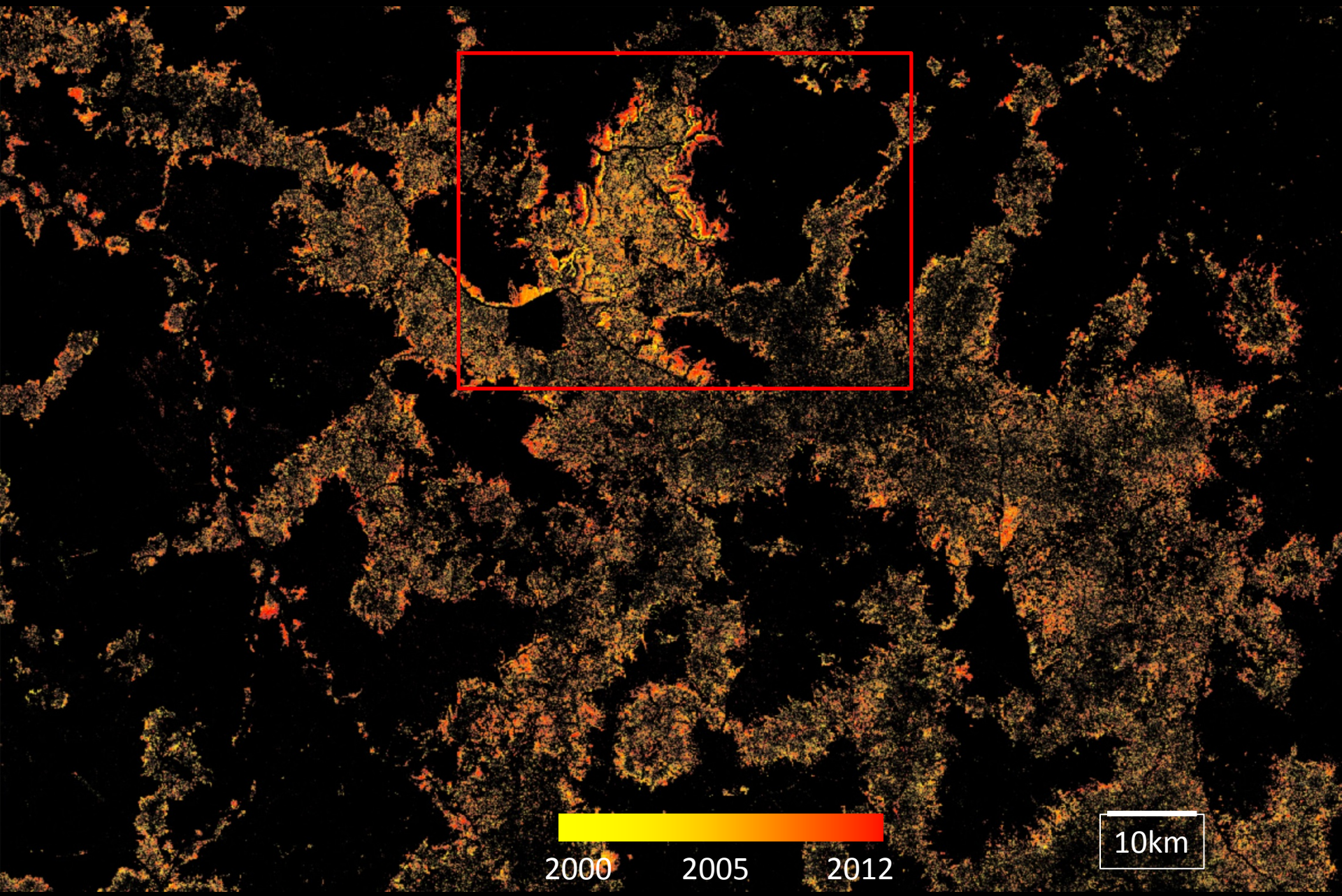


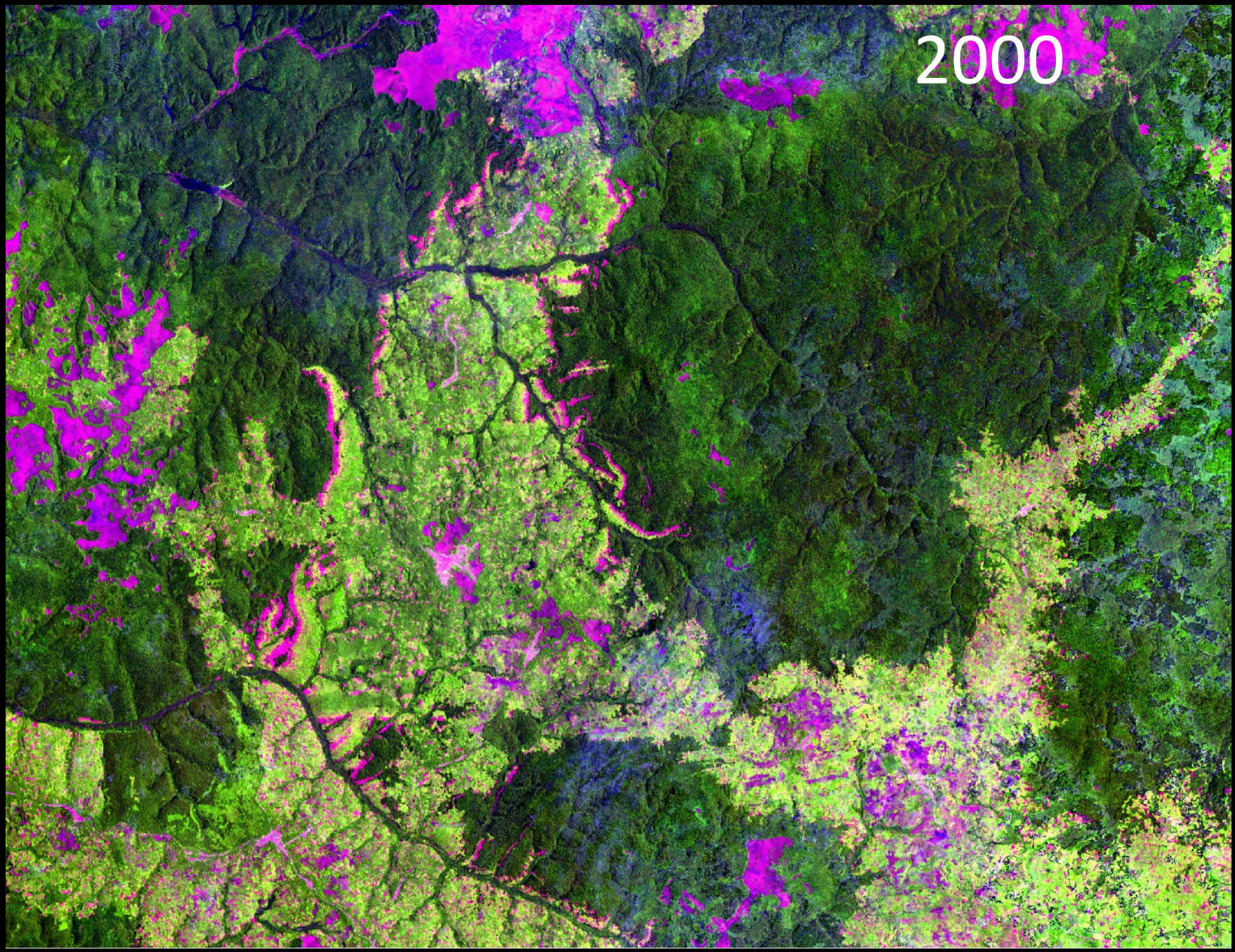

2000
2005
2012

Forest cover loss in vicinity of Mweka, DRC



Forest cover loss in vicinity of Mweka, DRC

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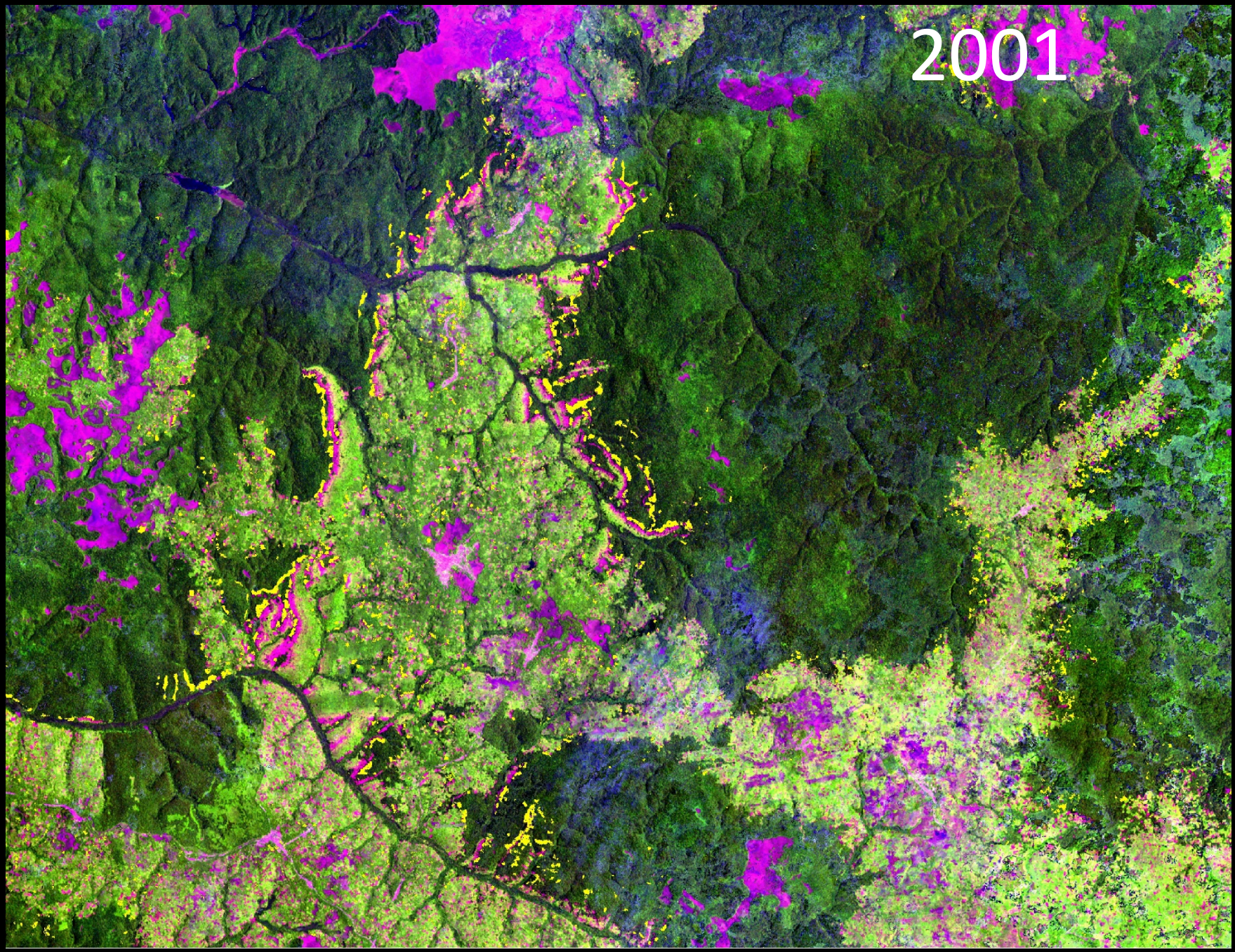
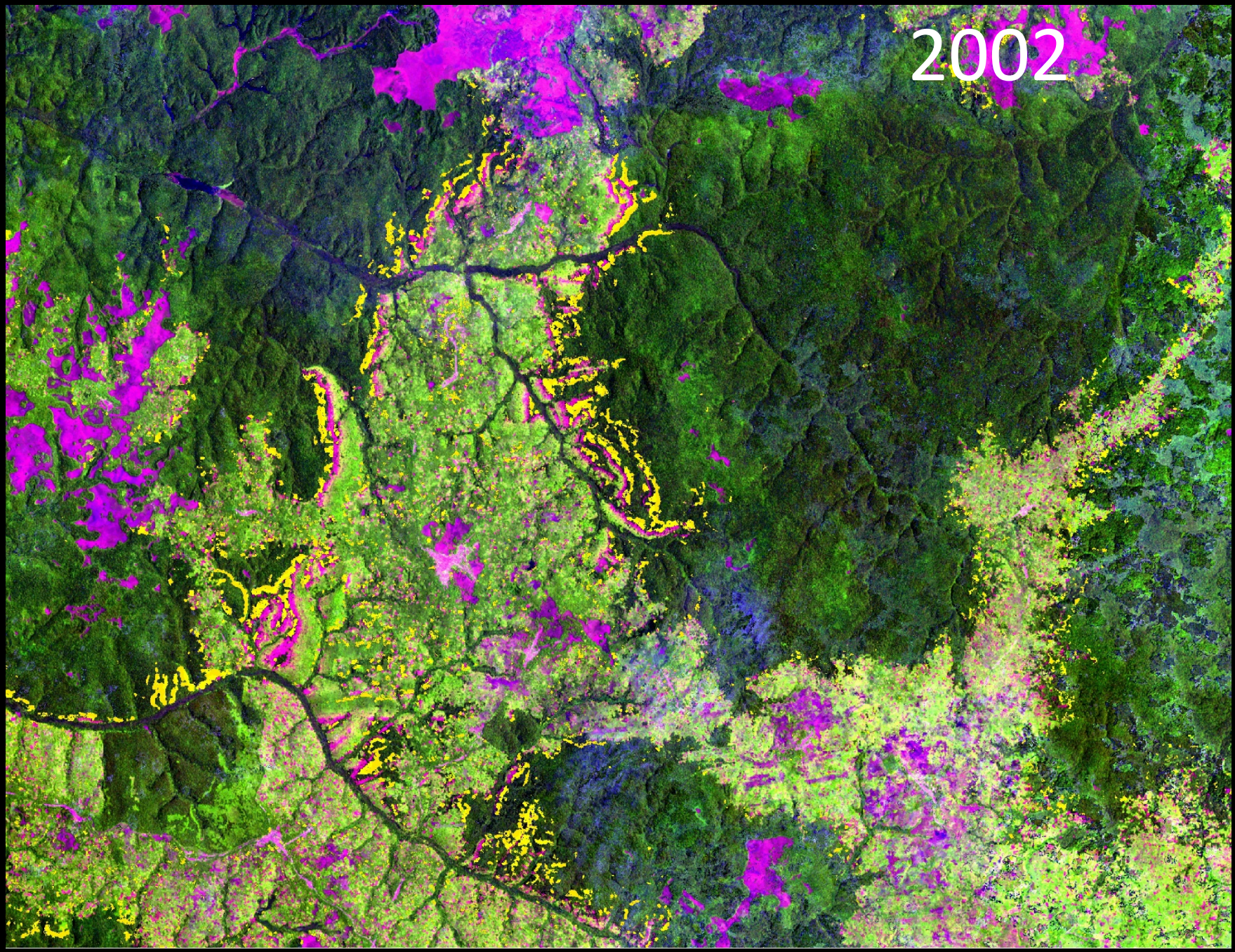

2001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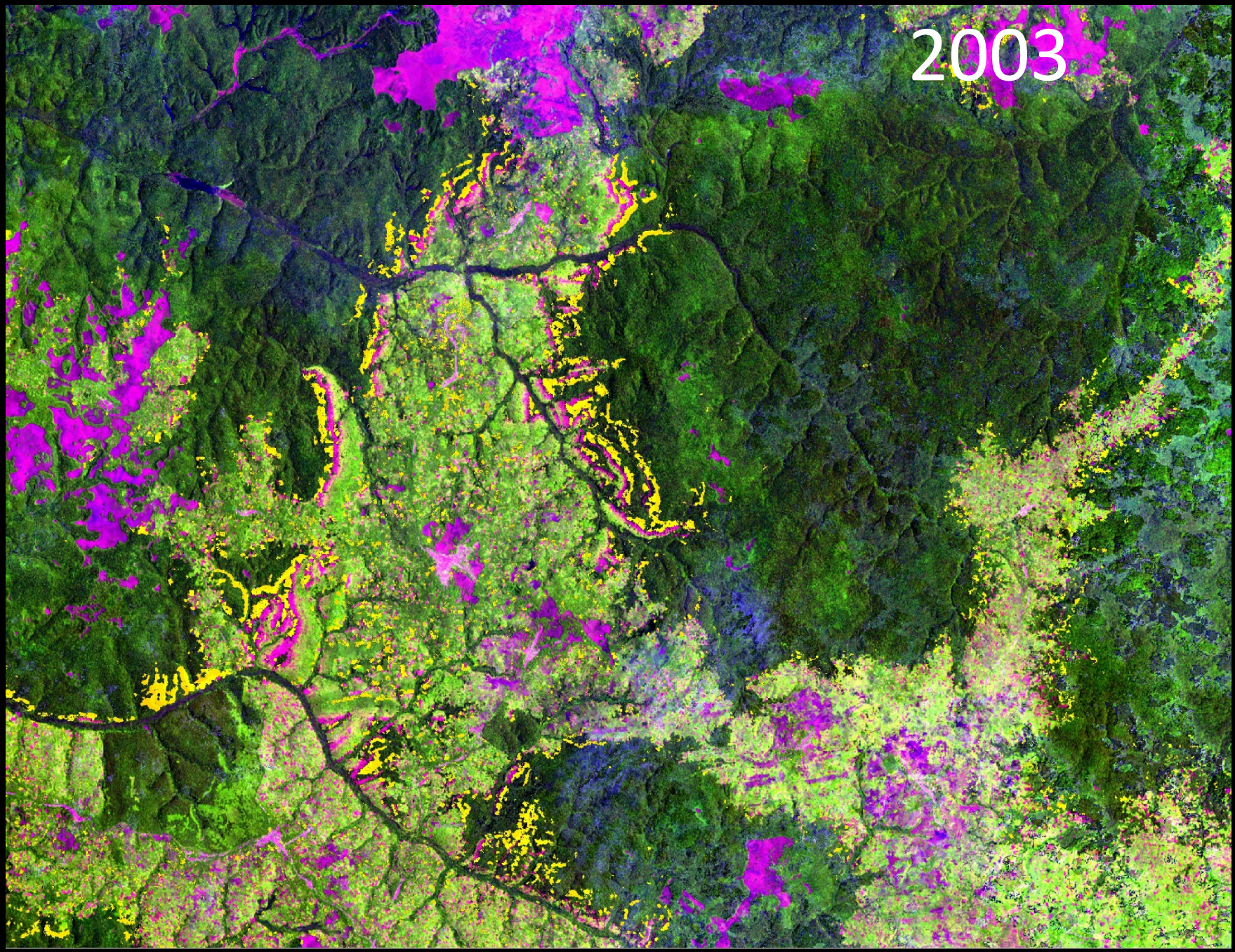
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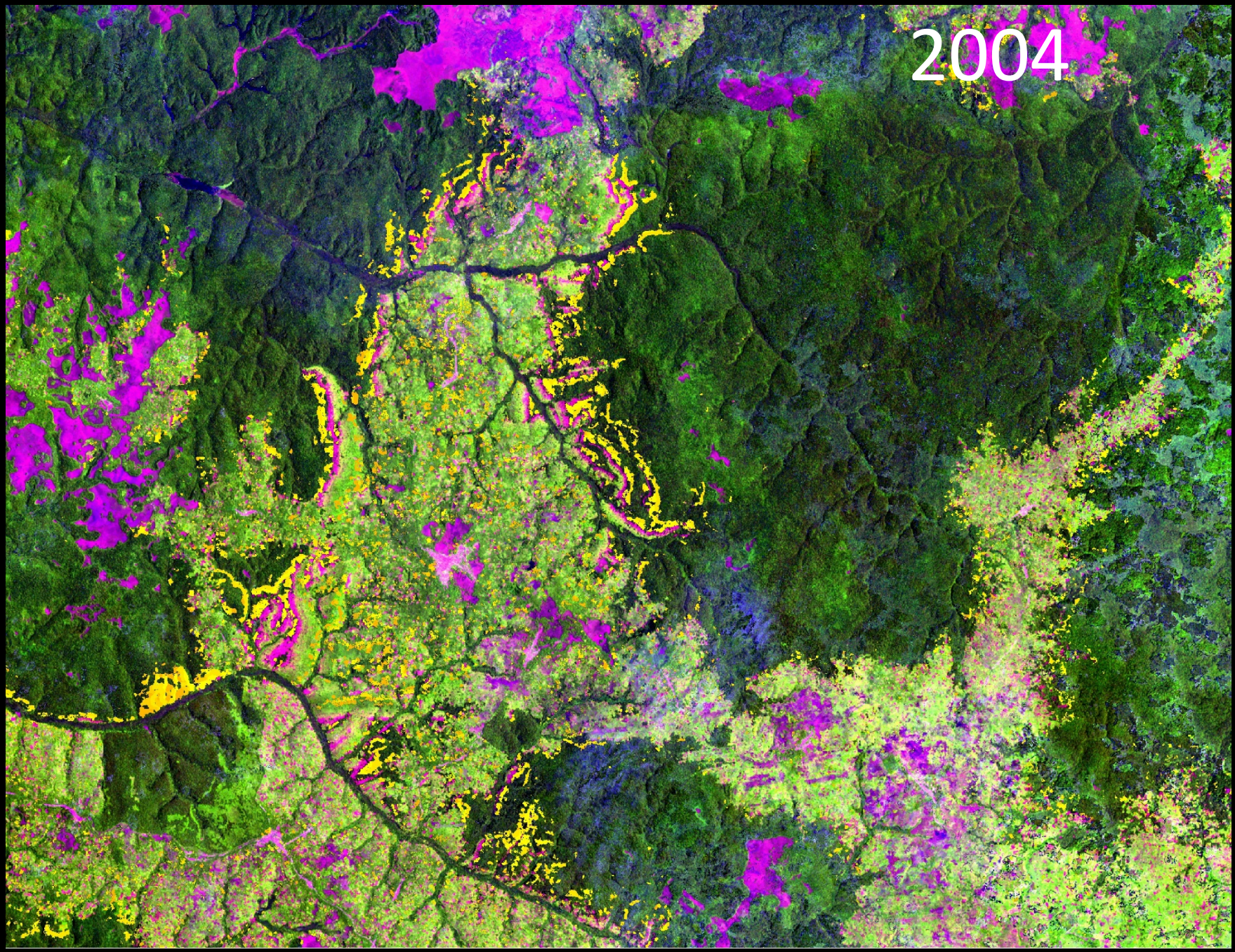
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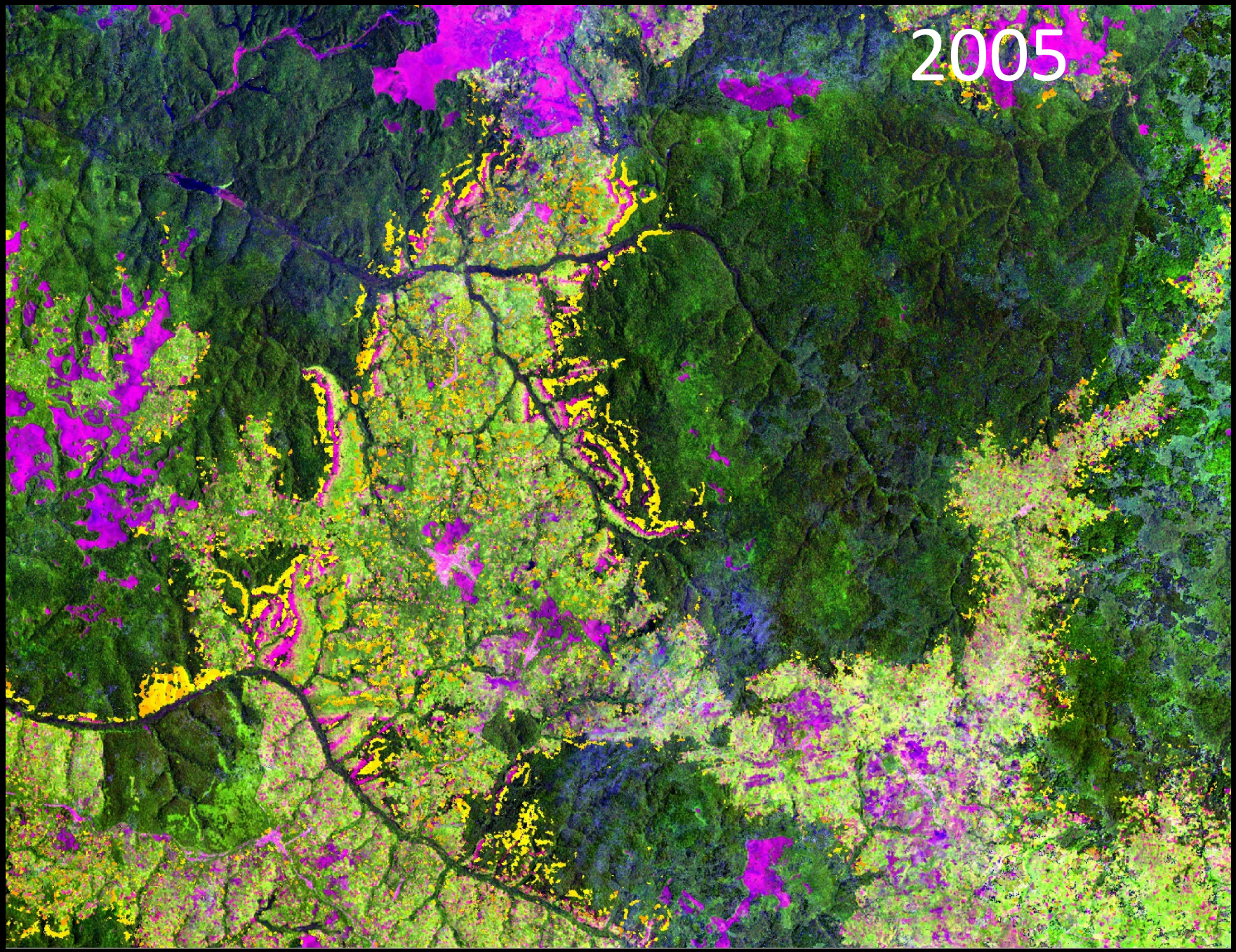
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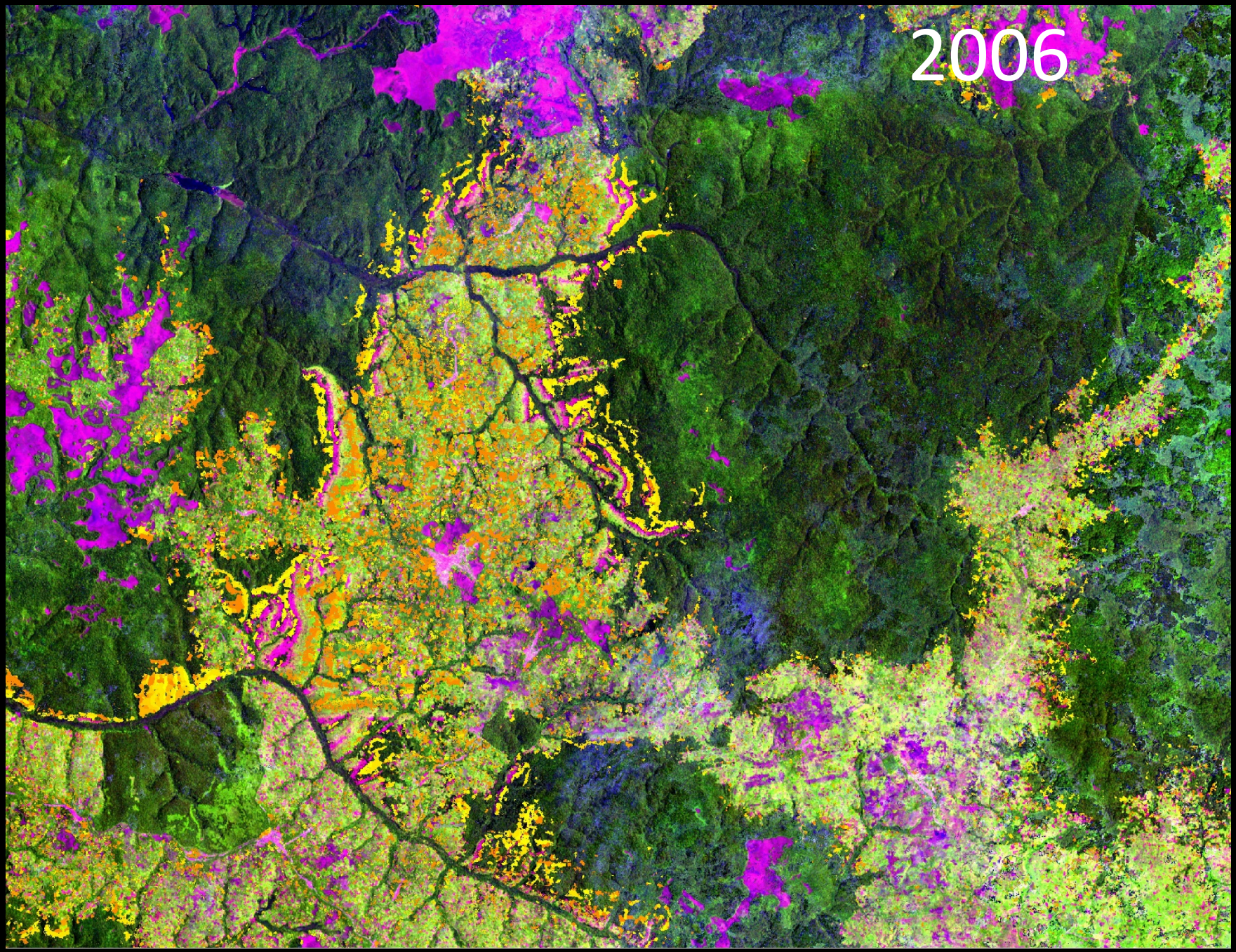
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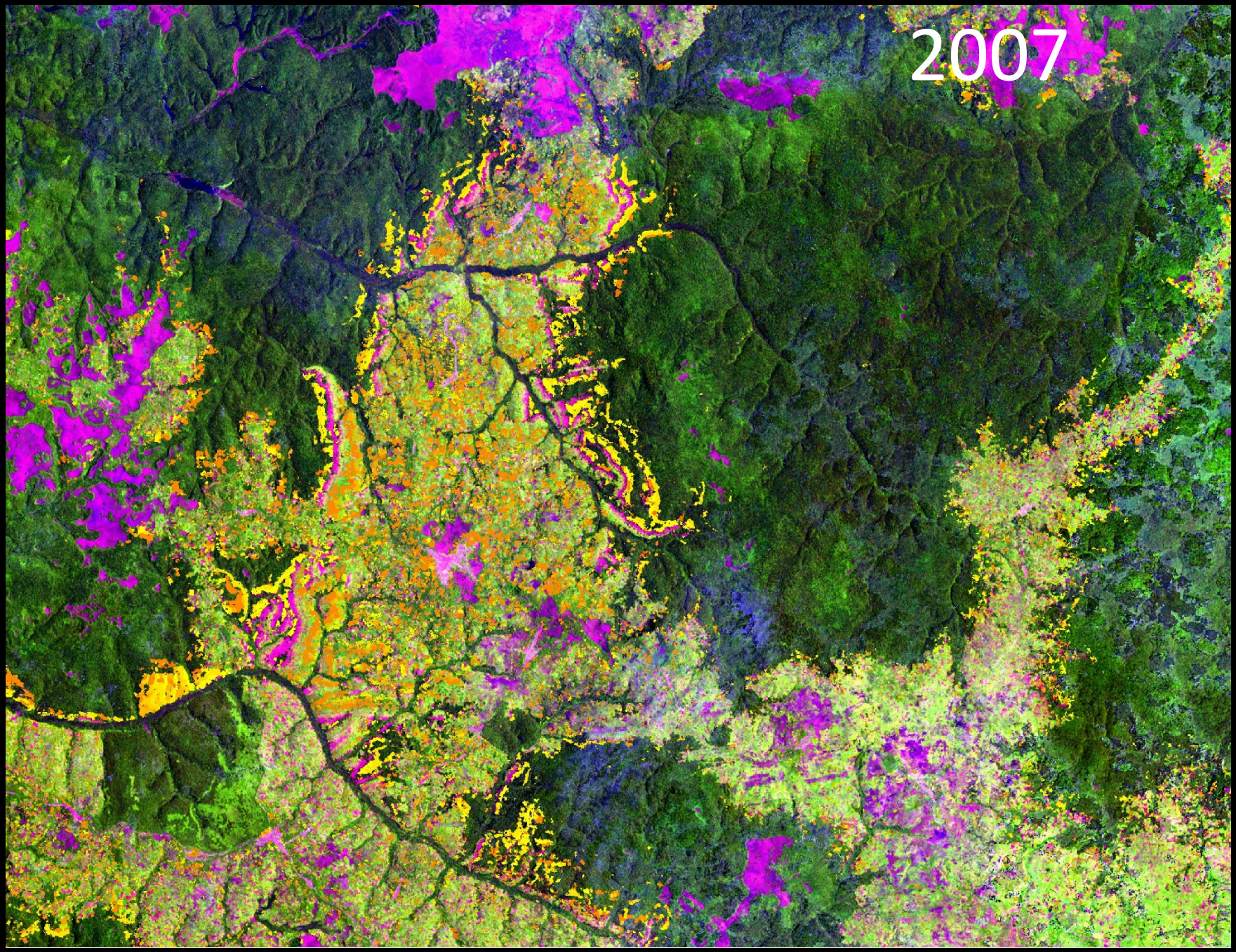
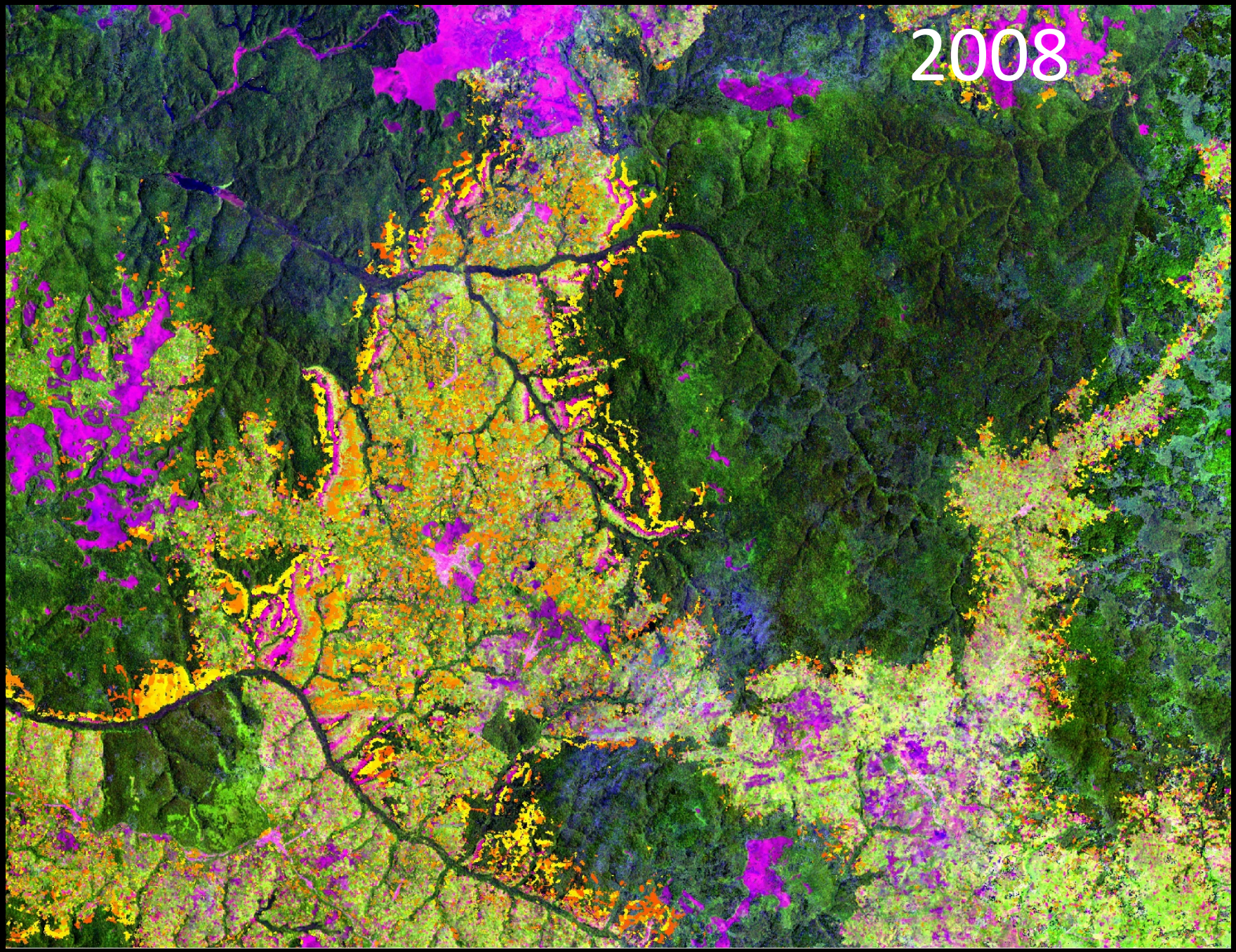
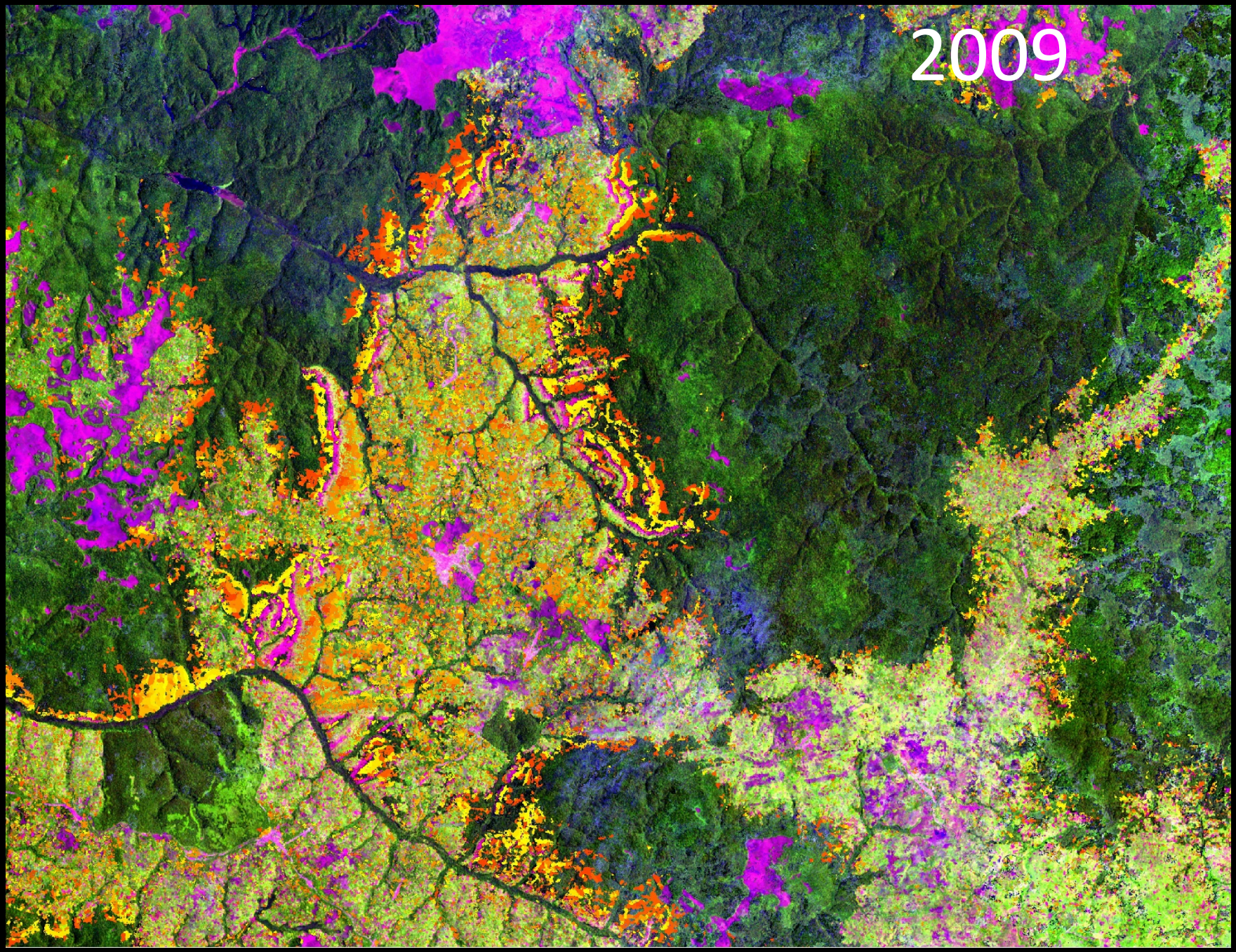

2007


2008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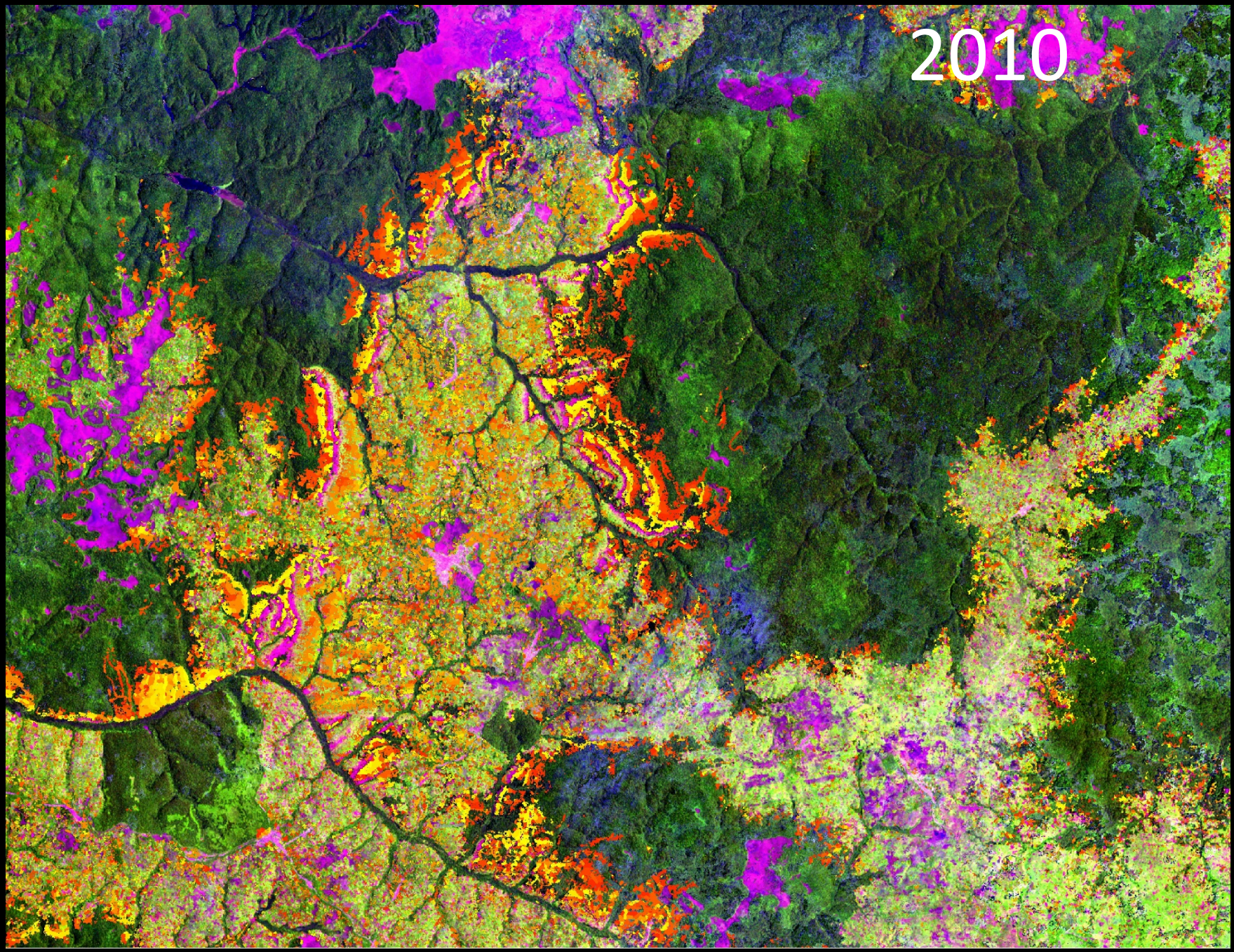
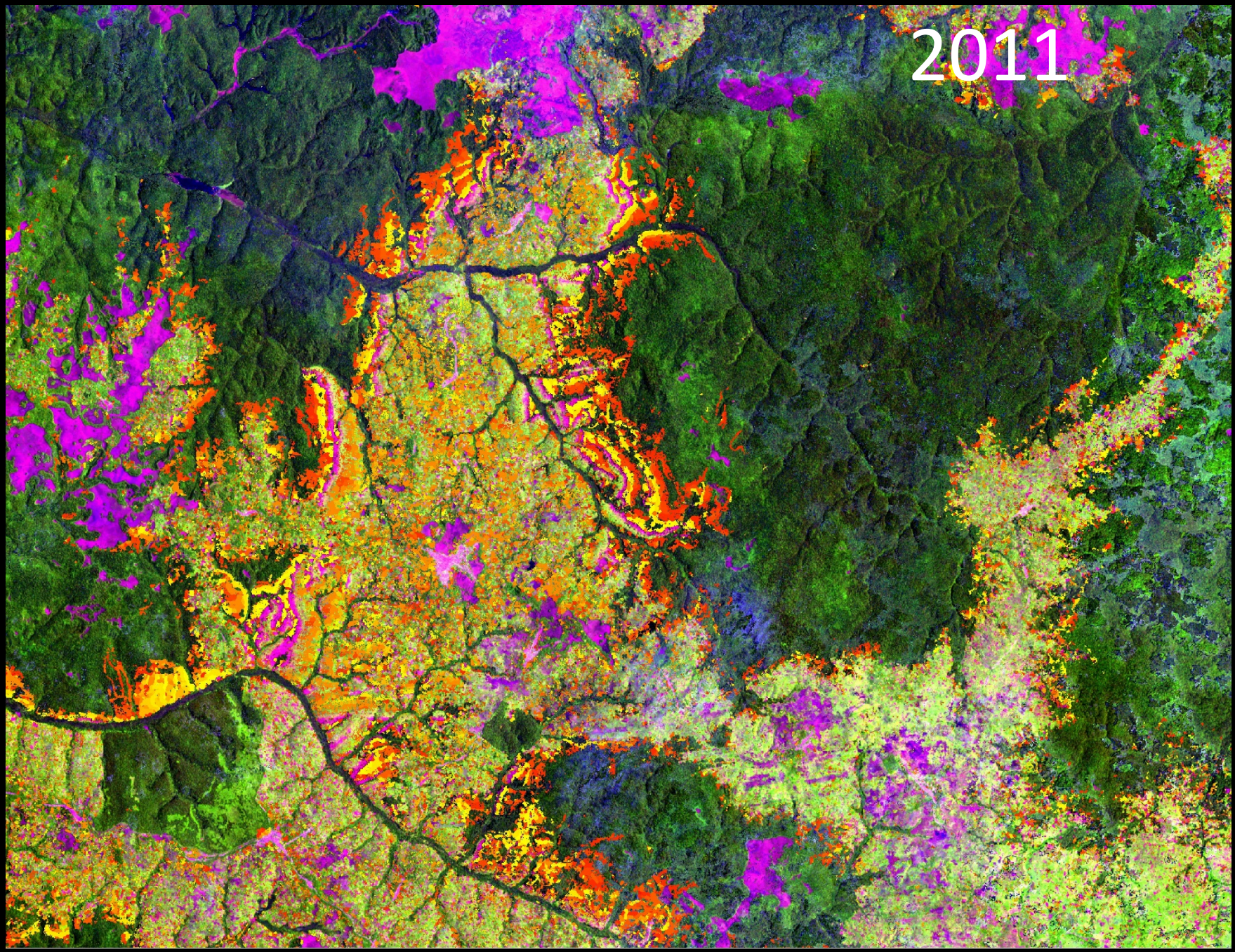
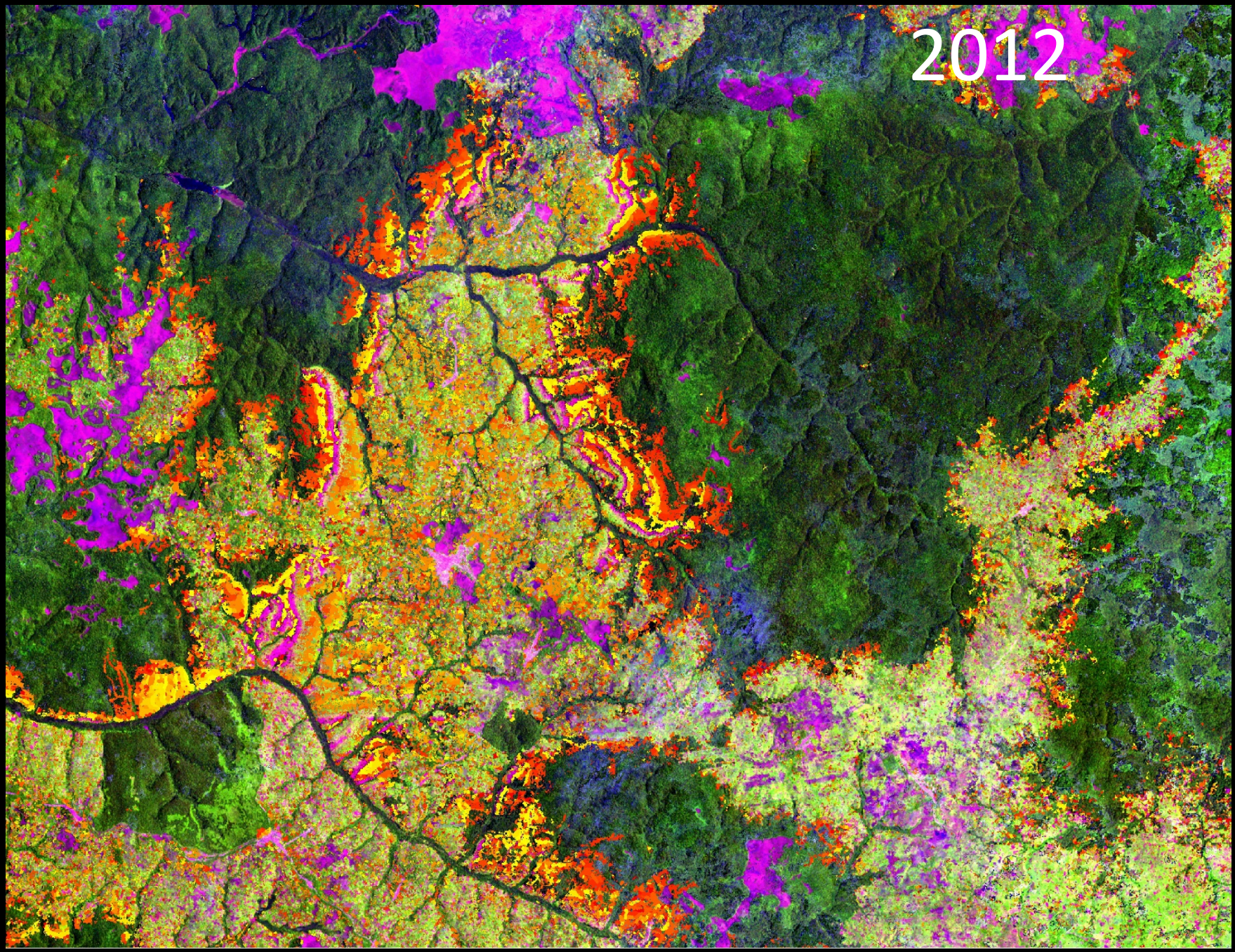
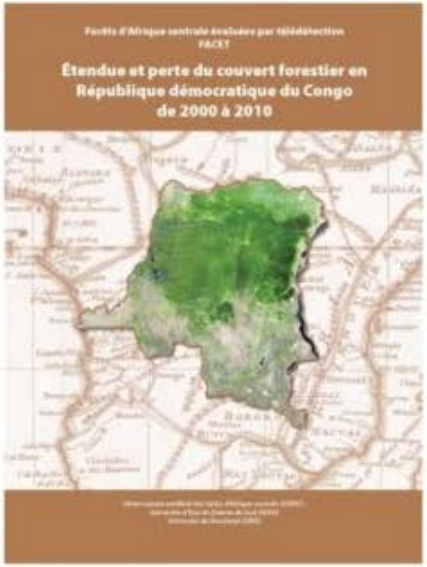
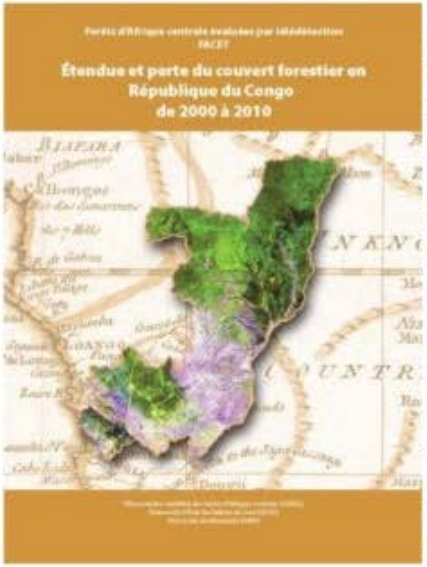

2010


2011


2012

Forest cover and loss in the Central Africa countries from 2000 to 2010





These atlas were produced as a part of the OSFAC (Observatoire Satellital des Forêts d'Afrique Centrale) initiative "Monitoring the forests of Central Africa using remotely sensed data sets" (FACET in French). FACET is led by OSFAC in collaboration with South Dakota State University and the University of Maryland, and supported by USAID CARPE. Additional support was provided by World Resources Institute.

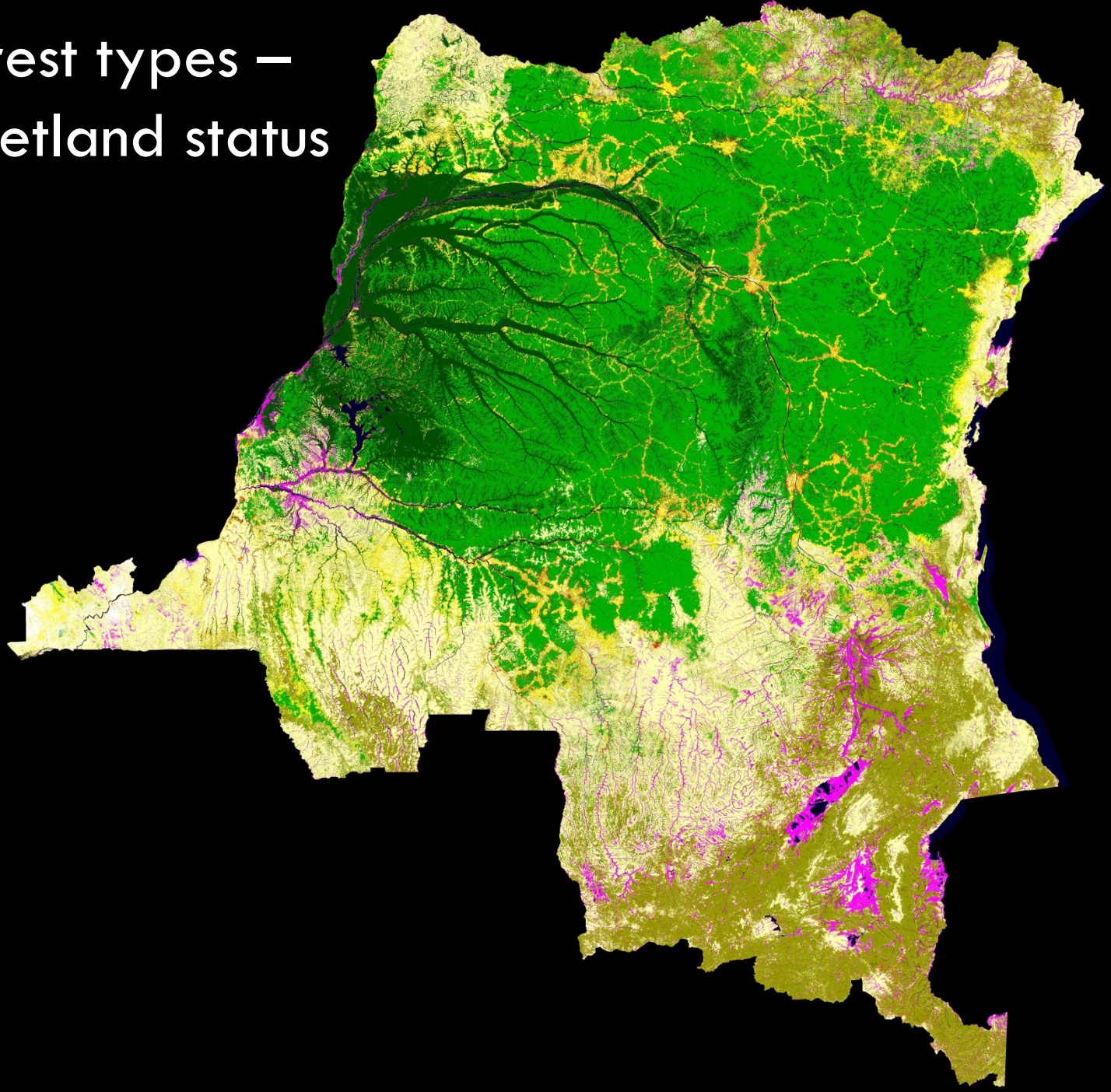
FACET (Central African Forests Remotely Assessed) is a OSFAC project whose goal is to quantify the spatiotemporal dynamics of the forest change in Central Africa through the use of multi-temporal satellite data. The series of multi-temporal data of the FACET project will also be a useful addition to many projects, including: monitoring of biodiversity, climate modeling and biogeochemical data, the natural resource management and planning of the use of soils. The results of the FACET project will describe as the loss of forest cover through deforestation or degradation that its expansion by reforestation or afforestation. All results will be made available to the public.

FACET publications are the result of an analysis by OSFAC which was used to map the extent of forest cover and changes in Central Africa.

The method used is the "wall-to-wall", a method developed jointly by the universities of South Dakota and Maryland. It is an adaptation of the approach of Hansen et al. (2008). MODIS Satellite data (Moderate Resolution Imaging Spectroradiometer) were used to pretreat the Landsat series, themselves used to characterize the extension and the loss of the forest cover. Landsat ETM + data were sampled at a spatial resolution of 60 meters. Mapping the extent and loss of forest cover by Landsat is severely limited to areas permanently covered by clouds. MODIS data were used to overcome this problem. The forest was defined as a space occupied by trees over 5 meters in height and having a canopy density of above 30%.

Primary forest is defined as a mature forest with a canopy density of above 60%. Secondary forest is a forest that has delayed and whose canopy covers more than 60% of the soil surface. A wood (woodland) is characterized by a density of forest cover between 30% and 60%. The swamp forest is defined as a primary forest located on a wetland. Wetlands are

FACET forest types – including wetland status



- Humid tropical forest
- Secondary forest
- Dry tropical woodland
- Non-forest
- Inundated grassland
- Water
- Swamp forest

Forest cover loss inside and outside DRC protected areas

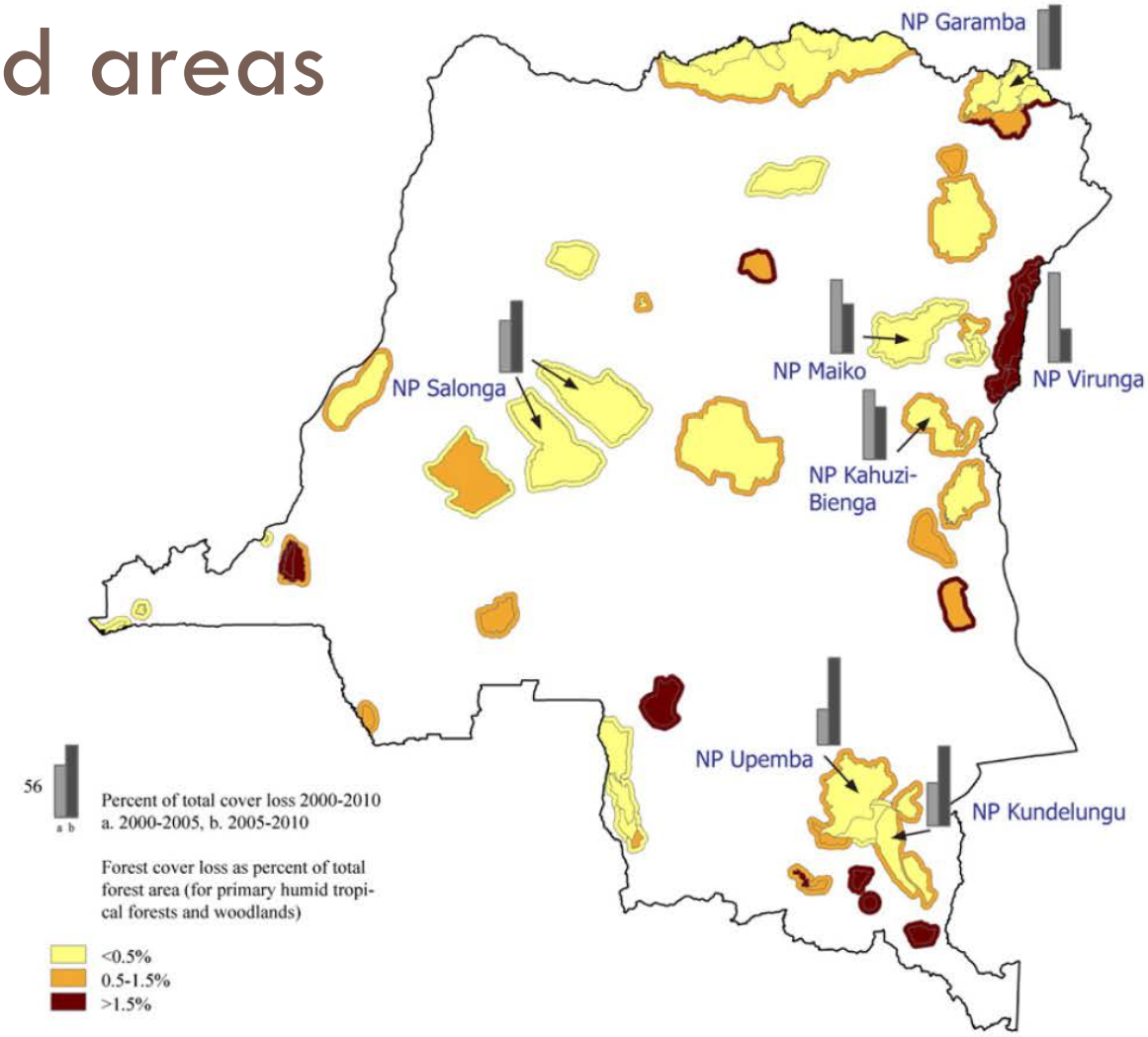
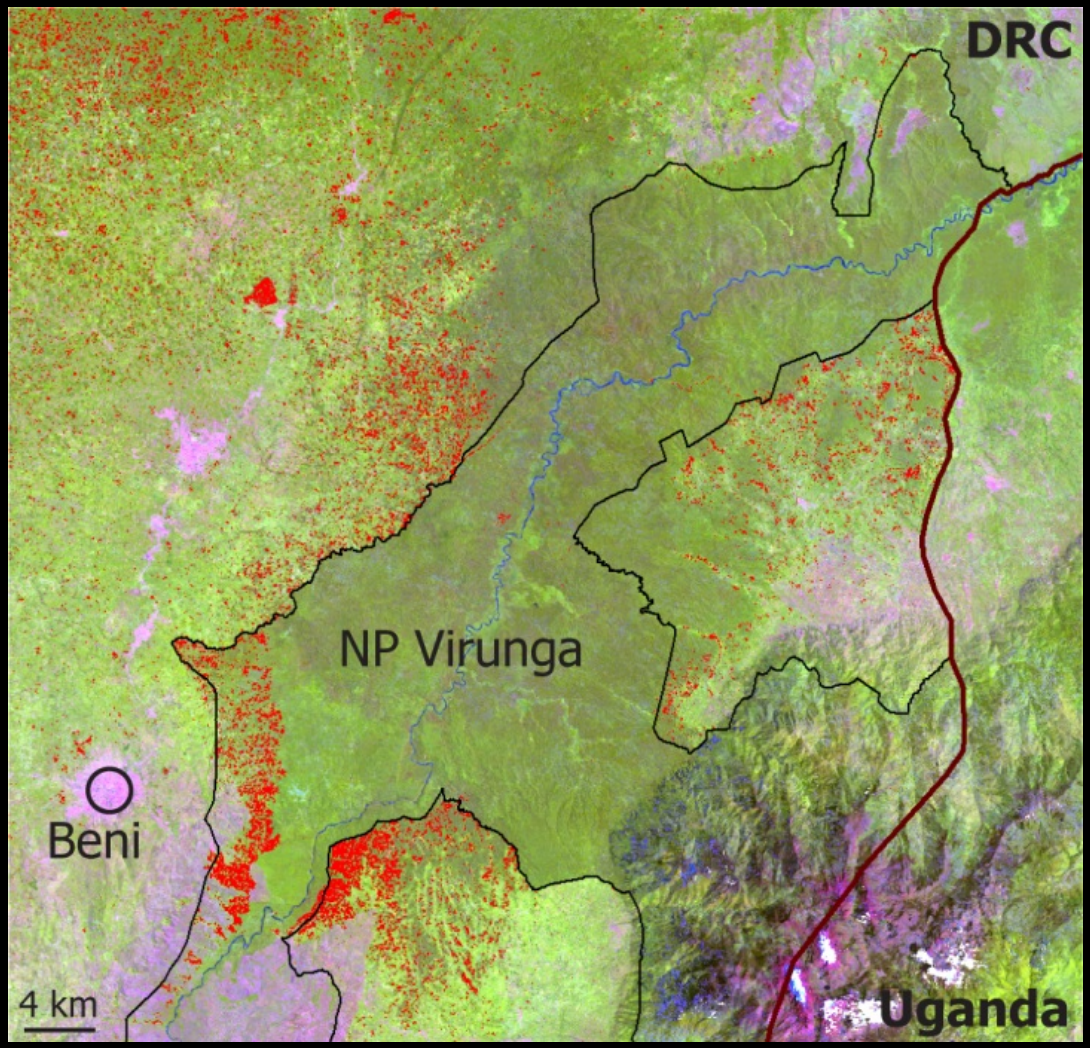


Fig. 5. Forest cover loss, 2000–2010, within officially designated nature protection areas and adjacent 10-km buffer zones. Percent of total forest cover loss for each 5-year interval is shown for National Parks. Only forest cover loss within primary humid tropical forests and woodlands were used for analysis.

Virunga National Park



Interactive Forest Atlas for Democratic Republic of Congo (Atlas Forestier Interactif de la Rép - Windows Internet Explorer

http://www.wri.org/publication/interactive-forest-atlas-democratic-republic-of-congo

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Interactive Forest Atlas for Democratic Republic of Congo (Atlas Forestier Interactif de la République Démocratique du Congo)

Lyna Bélanger, Benoit Mertens

January, 2011

Tags: africa deforestation DRC forests mapping

The Interactive Forest Atlas is both an information management tool and an aid to decision makers working to support the sustainable use of forest resources in the Democratic Republic of Congo.

Inquiries
Matthew Steil, Manager, Central Africa Forests
msteil@wri.org | +1 (202) 729-7762

Downloads

» Rapport Complet/Complete Report (in French) (PDF, 68 pages, 6.1 Mb)

GIS Data/Données

» Affectation territoriale (ZIP archive, 1.7 Mb)
» Conservation (ZIP archive, 1.6 Mb)
» Hydrographie (ZIP archive, 17.2 Mb)
» Infrastructure (ZIP archive, 6.6 Mb)
» Limite Administrative (ZIP archive, 2.5 Mb)
» Localite (ZIP archive, 138 Kb)
» Vegetation (ZIP archive, 5.5 Mb)

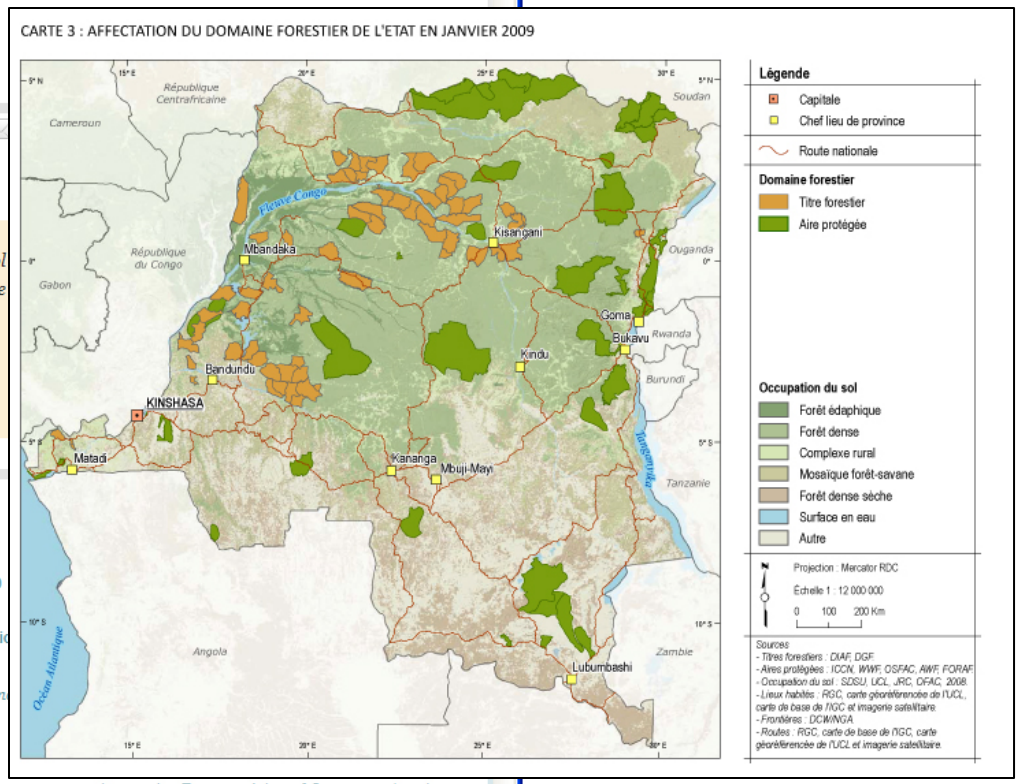
Charts and Maps

La République Démocratique du Congo: Affectation du Domaine Forestier de l'État en janvier 2009

La République Démocratique du Congo: Avancement de l'élaboratio des plans d'aménagement

More charts & m

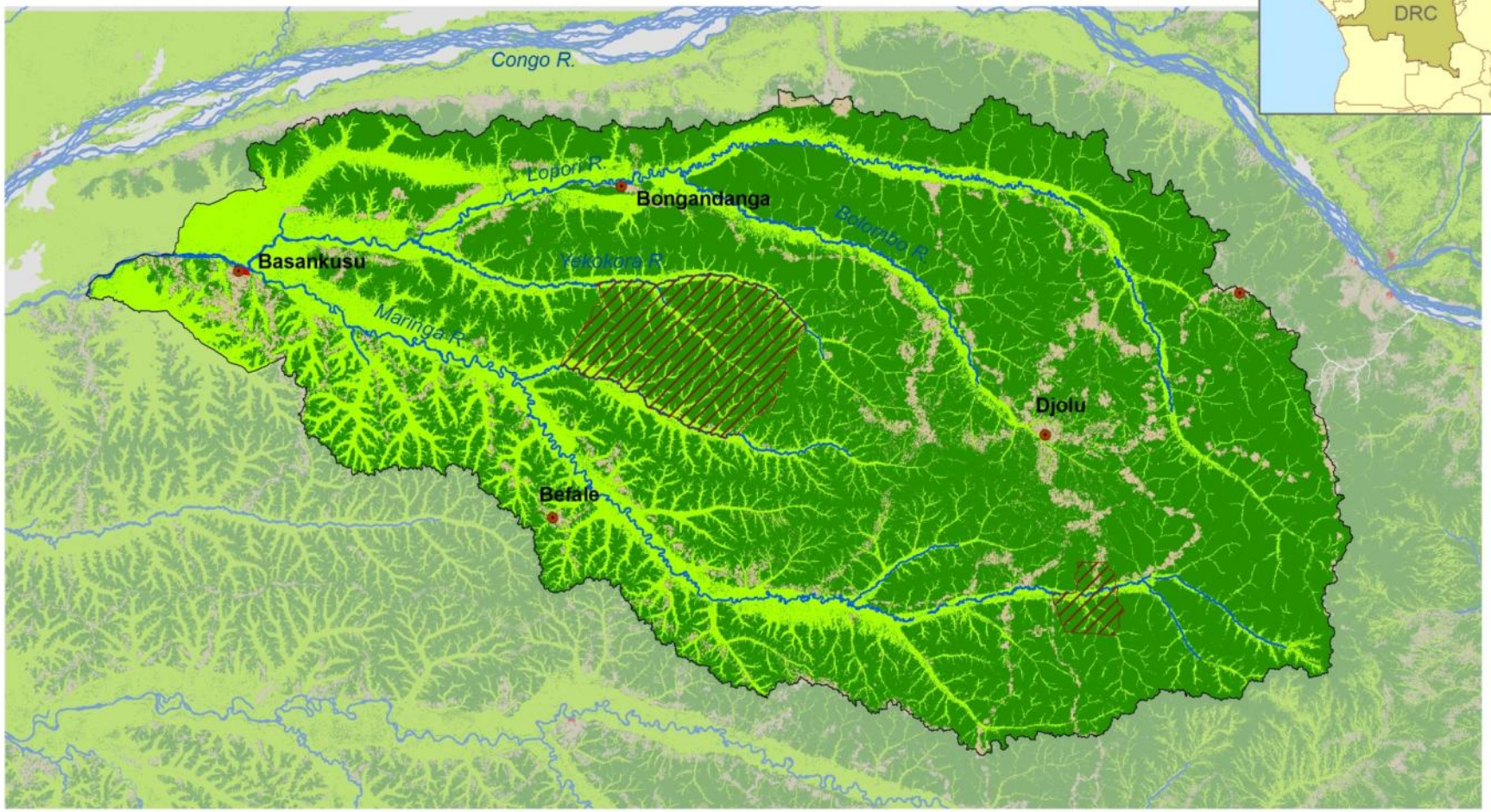
» Interactive Forestry Atlas of Cameroon (version 2.0)



http://www.wri.org/

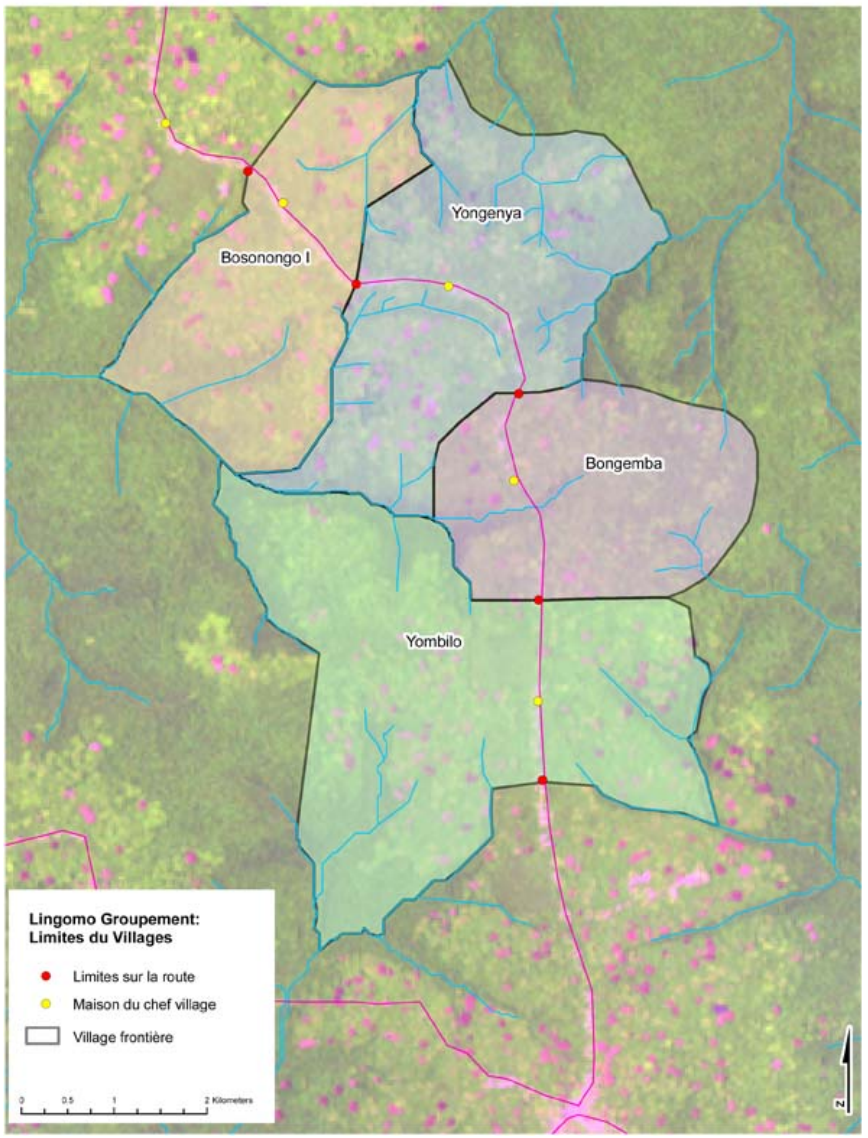
Internet 100%

The Maringa-Lopori-Wamba Landscape - AWF



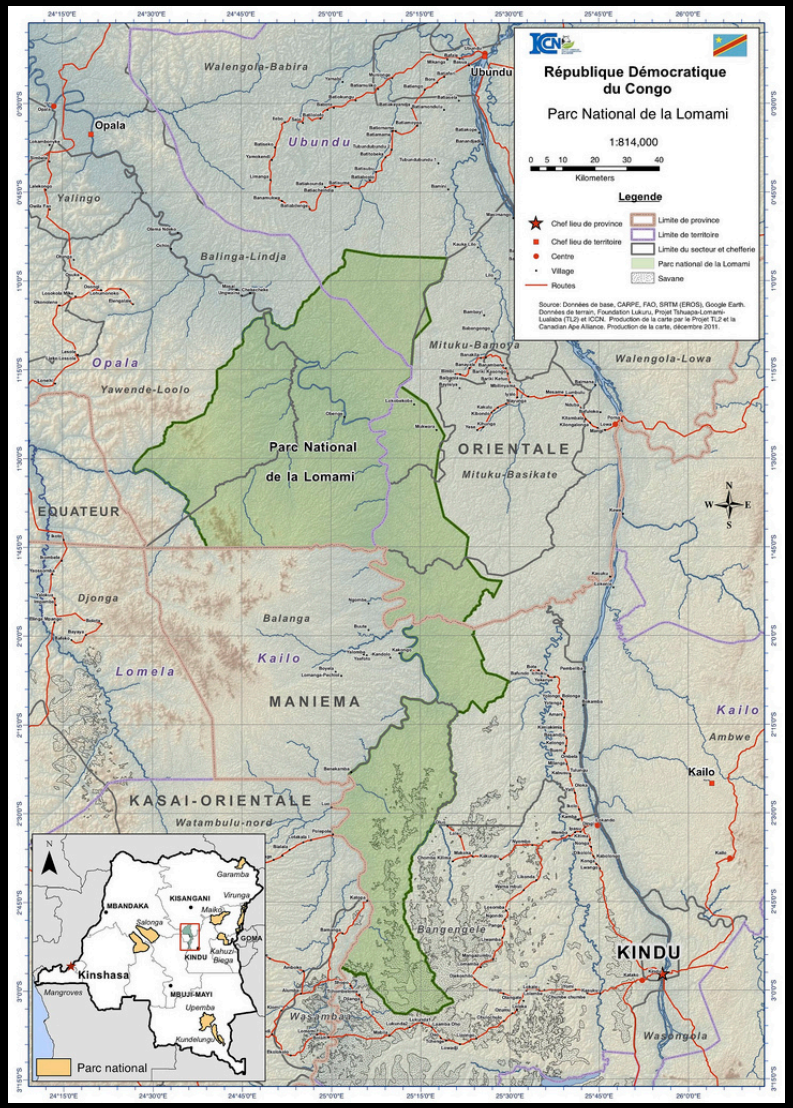
Sustainable Opportunities for Improving Livelihoods (SOIL) project study site (4,000 sq km)

Participatory Mapping for SOIL

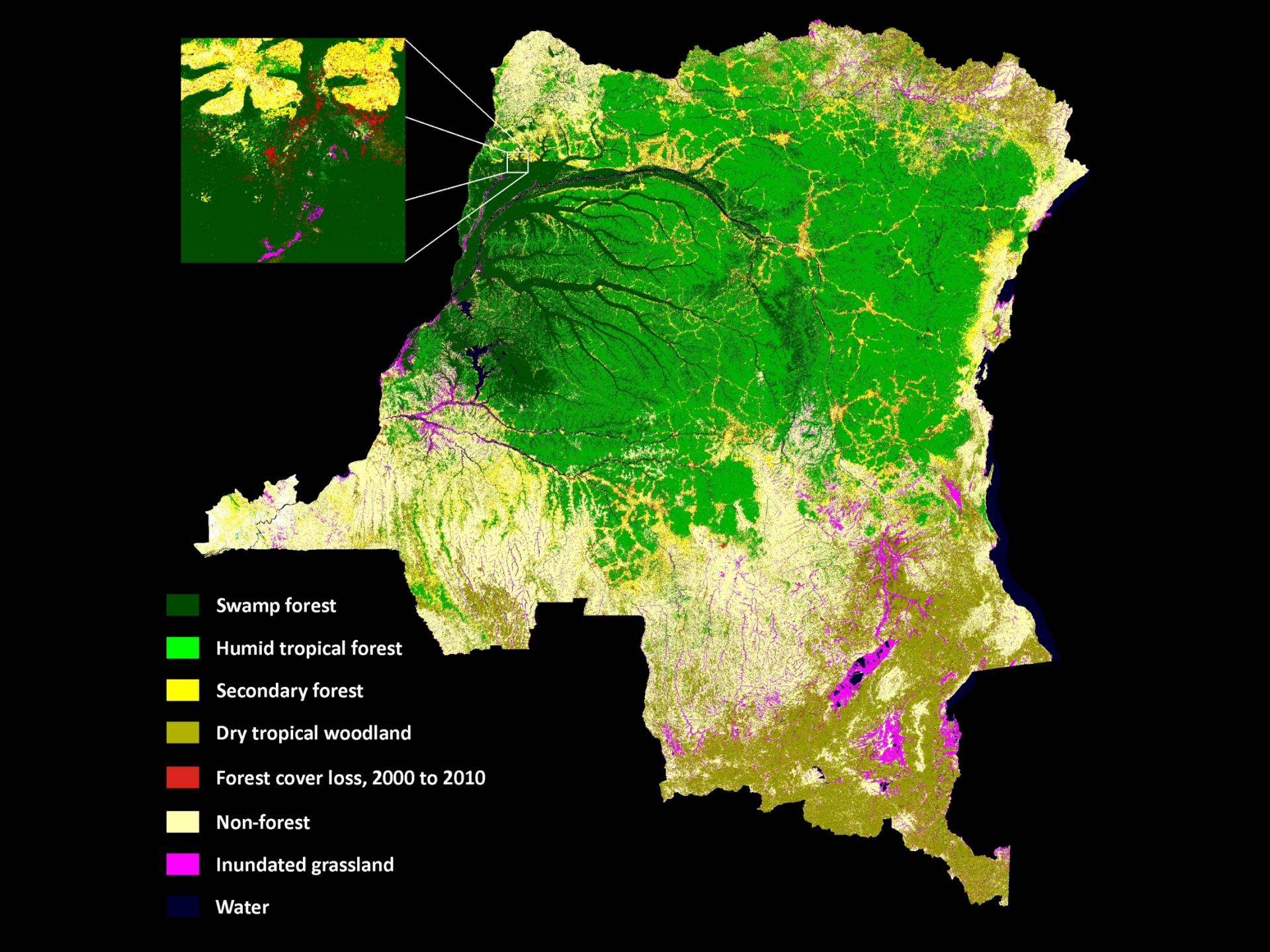


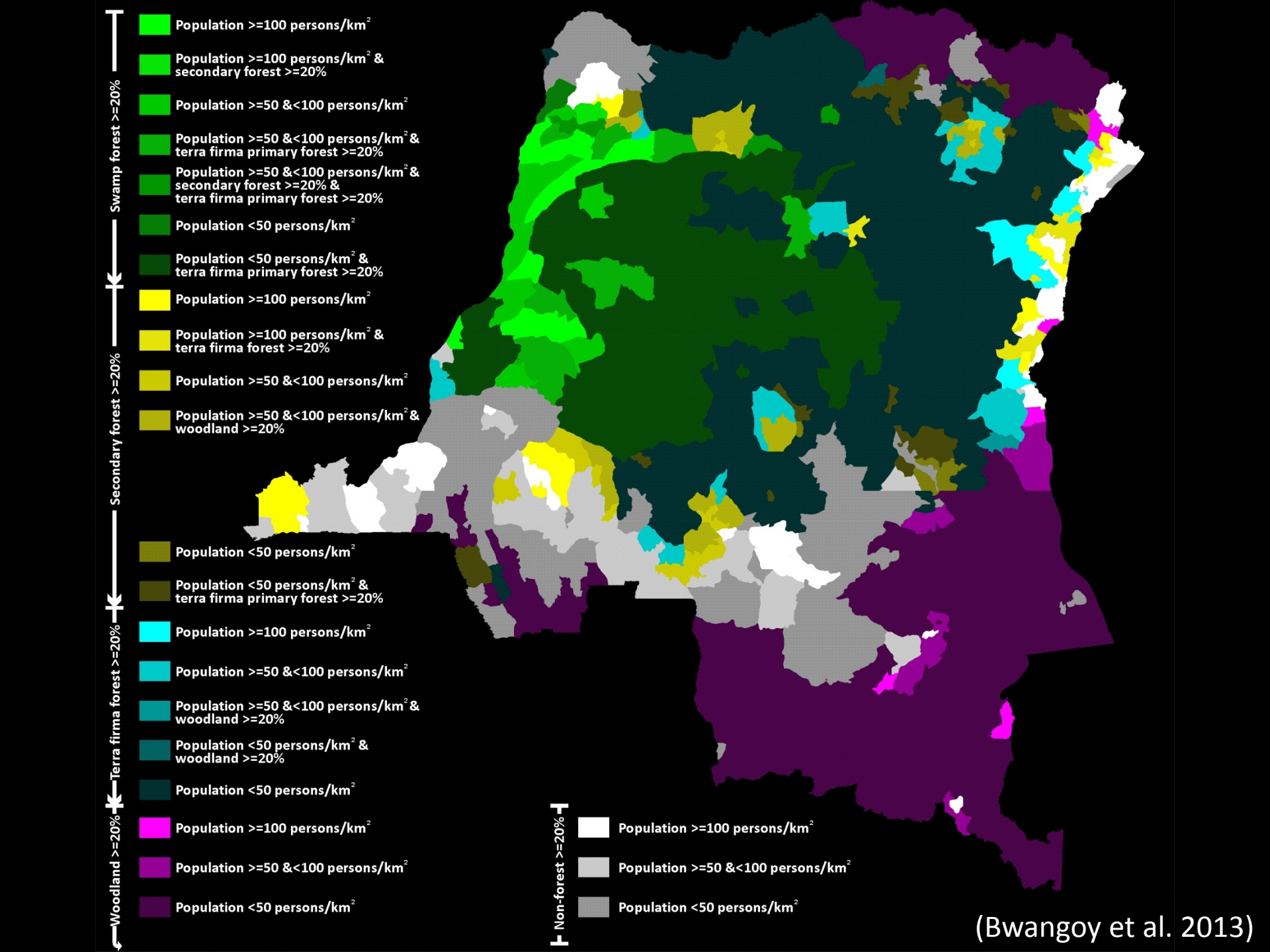
AFRICAN WILDLIFE FOUNDATION®

Tshuapa, Lomami and Lualaba Rivers (TL2)



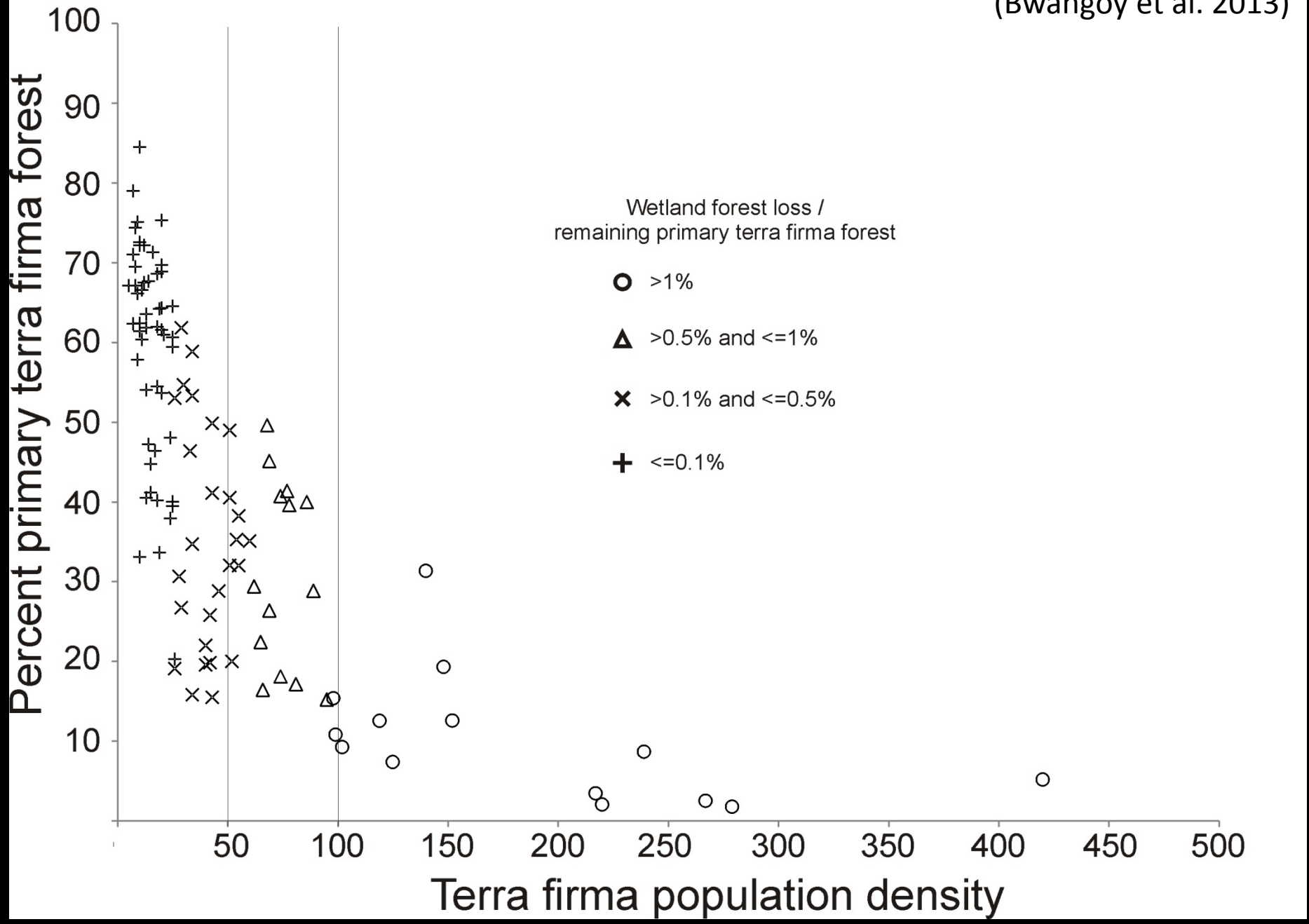
http://www.bonoboincongo.com John and Terese Hart


Swamp forest
Humid tropical forest
Secondary forest
Dry tropical woodland
Forest cover loss, 2000 to 2010
Non-forest
Inundated grassland
Water



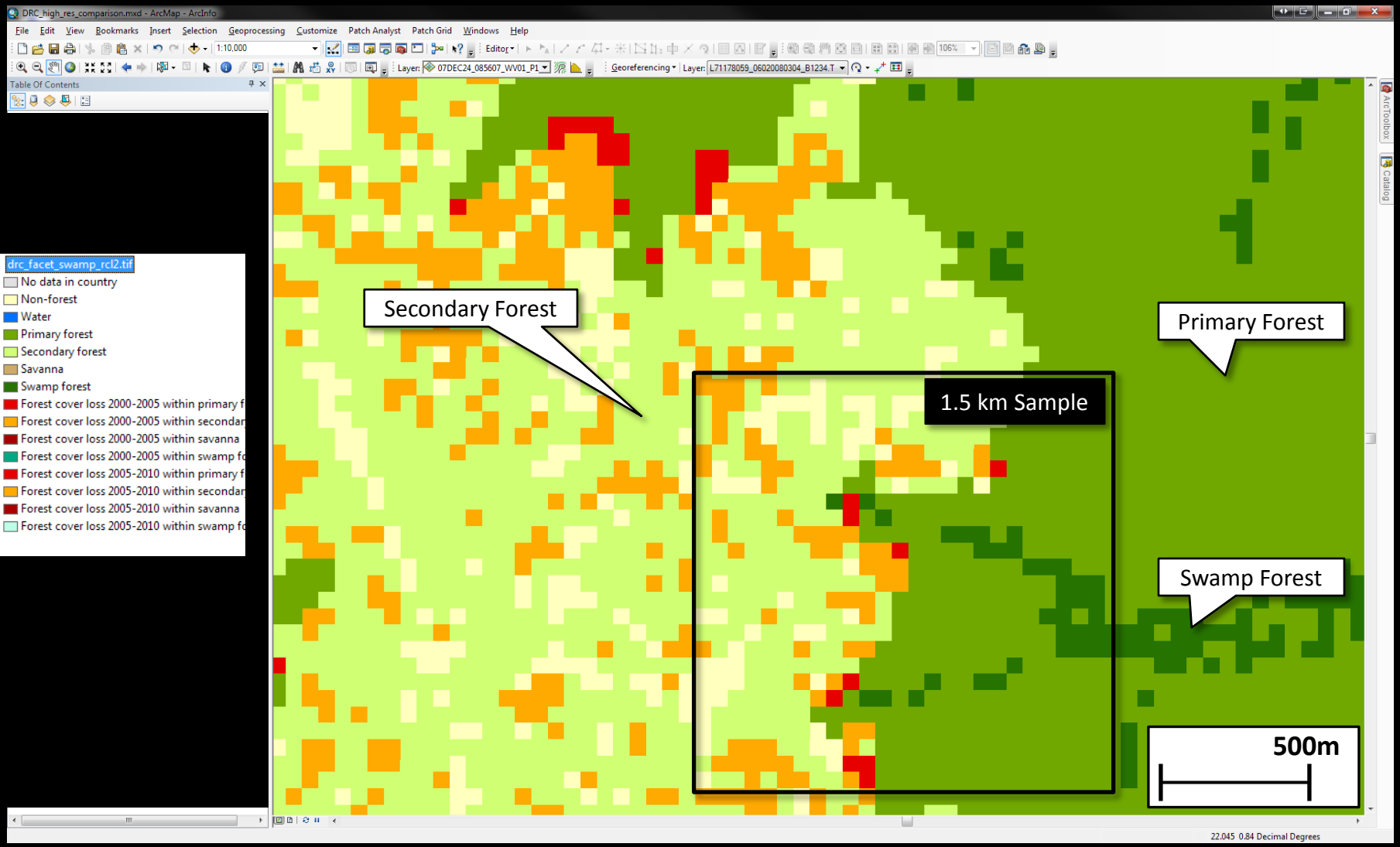
(Bwangoy et al. 2013)

(Bwangoy et al. 2013)



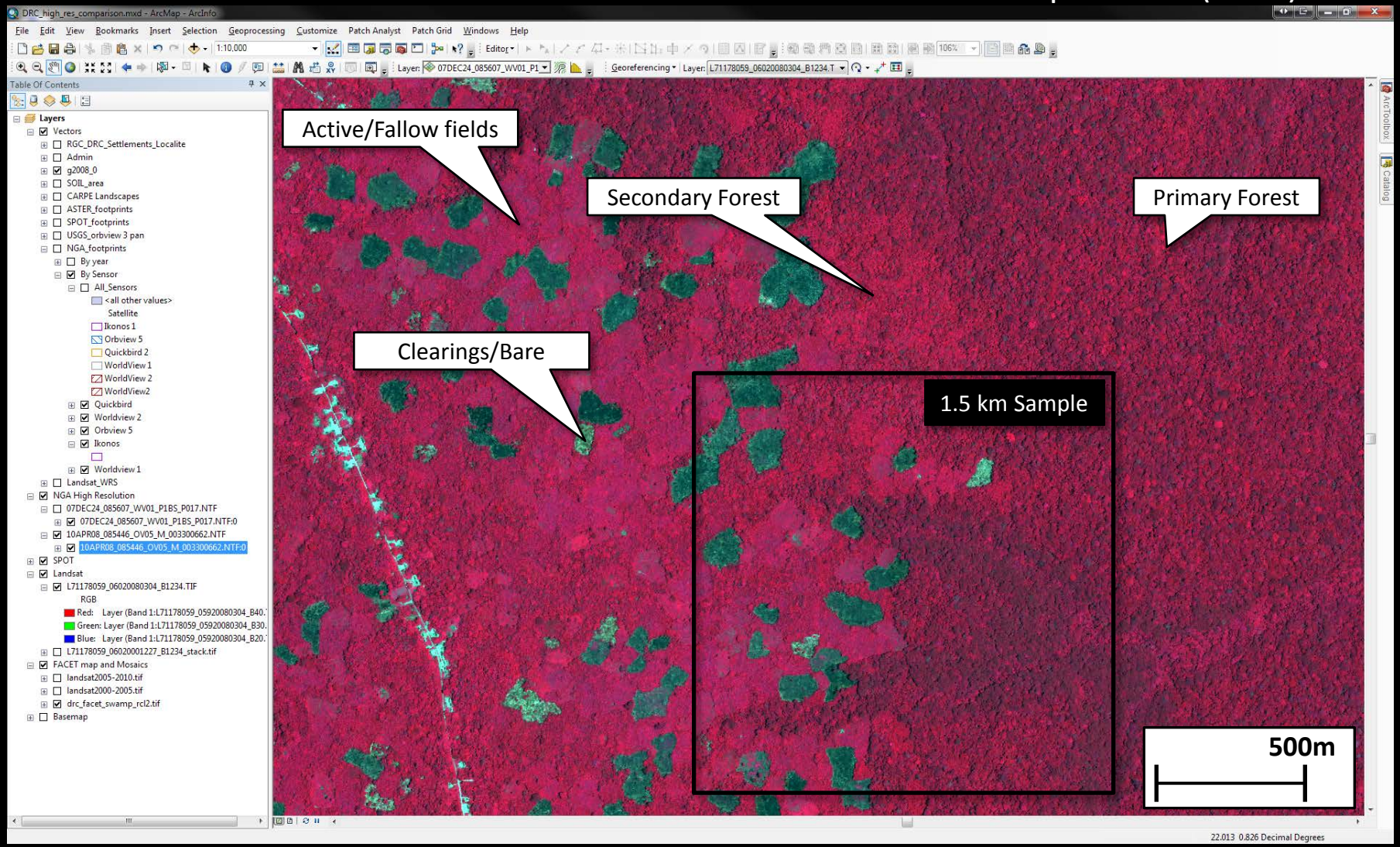
Using very high spatial resolution data to validate and adjust Landsat-derived area estimates

FACET (60m)



Using very high spatial resolution data to validate and adjust Landsat-derived area estimates

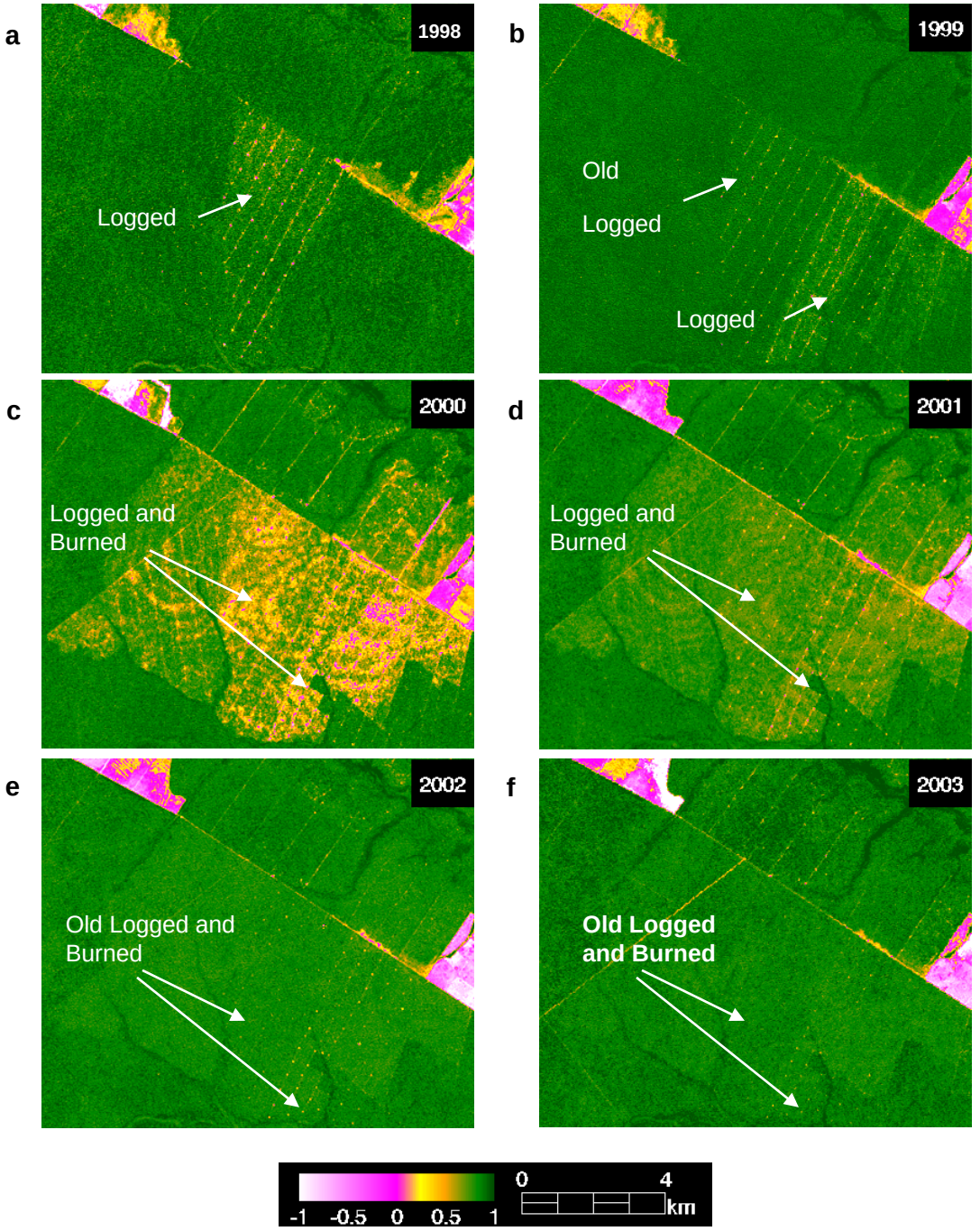
Orbview 5 false color - 10th of April 2008 (1.6m)



DRC and RoC training led by Patrick Lola Amani of OSFAC and UMd

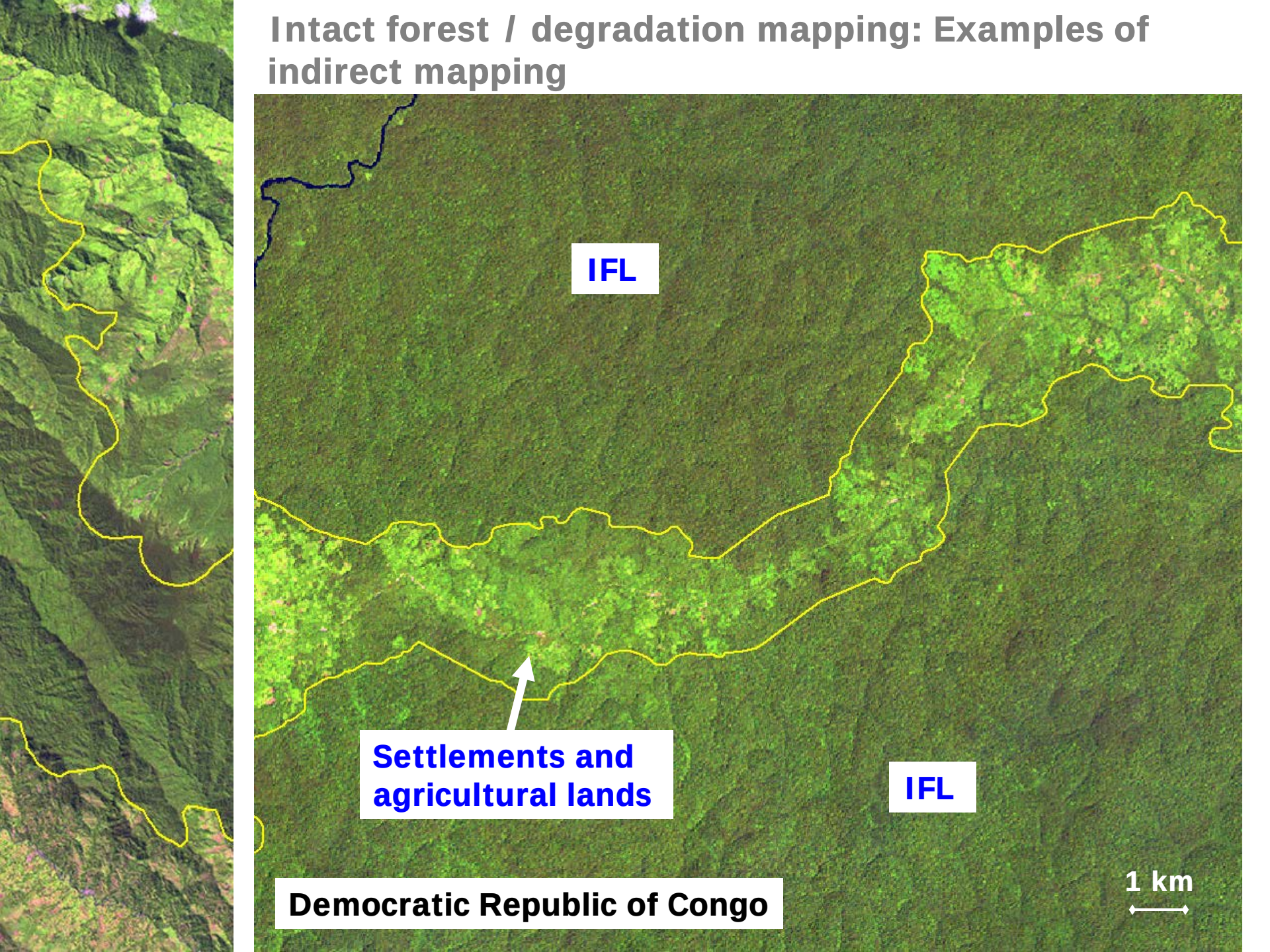
Dynamic of Forest Degradation

- 25% or more of canopy removal is required for direct observation of degradation using Landsat
- Degradation signal fades quickly
- If not imaged in proximity to the time of logging, the signal is quickly obscured
- For cloud-affected regions and/or areas with low intensity logging, direct observation and mapping of degradation is not possible with Landsat

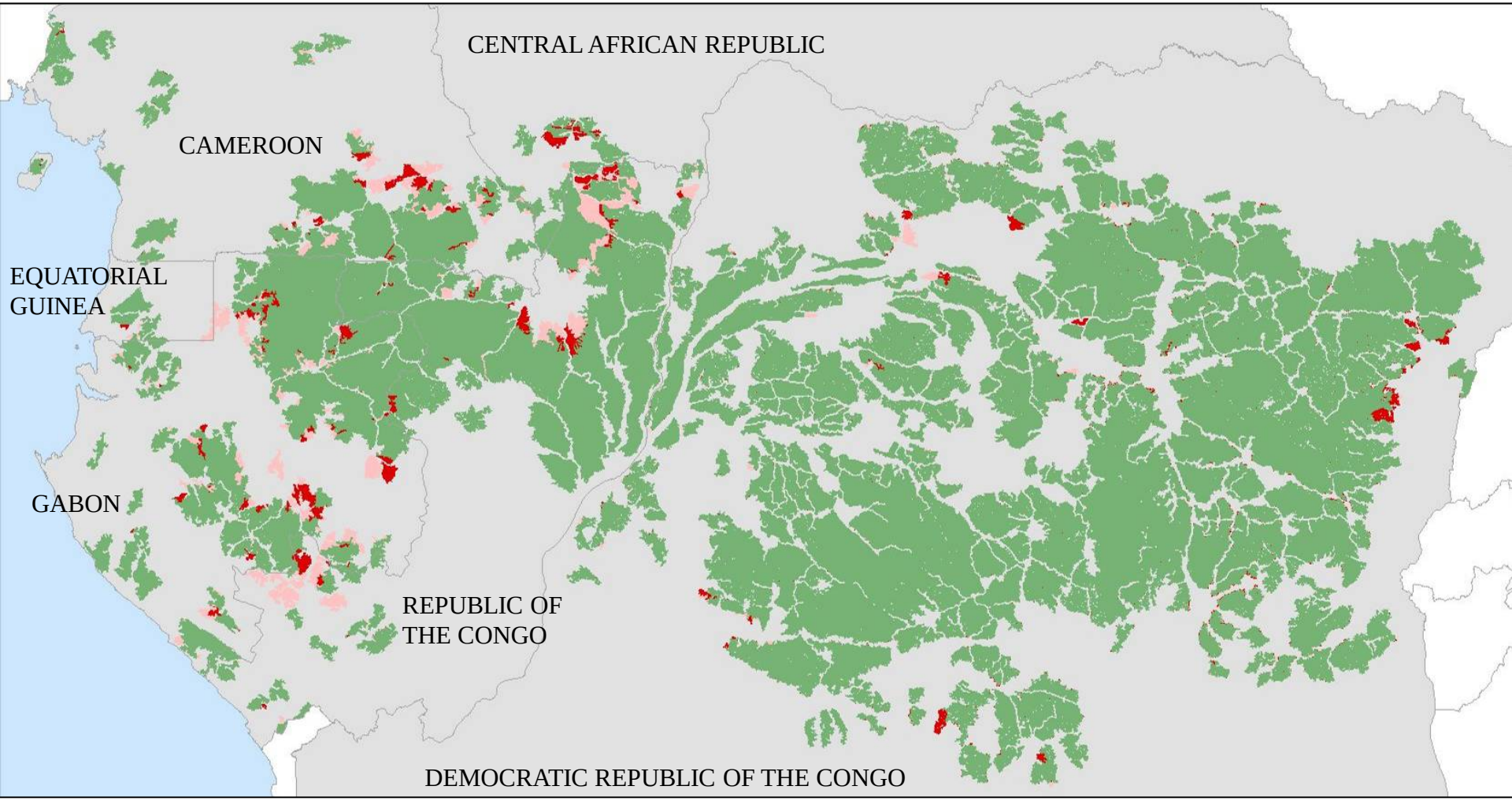


Carlos Souza, Imazon

Intact forest / degradation mapping: Examples of indirect mapping

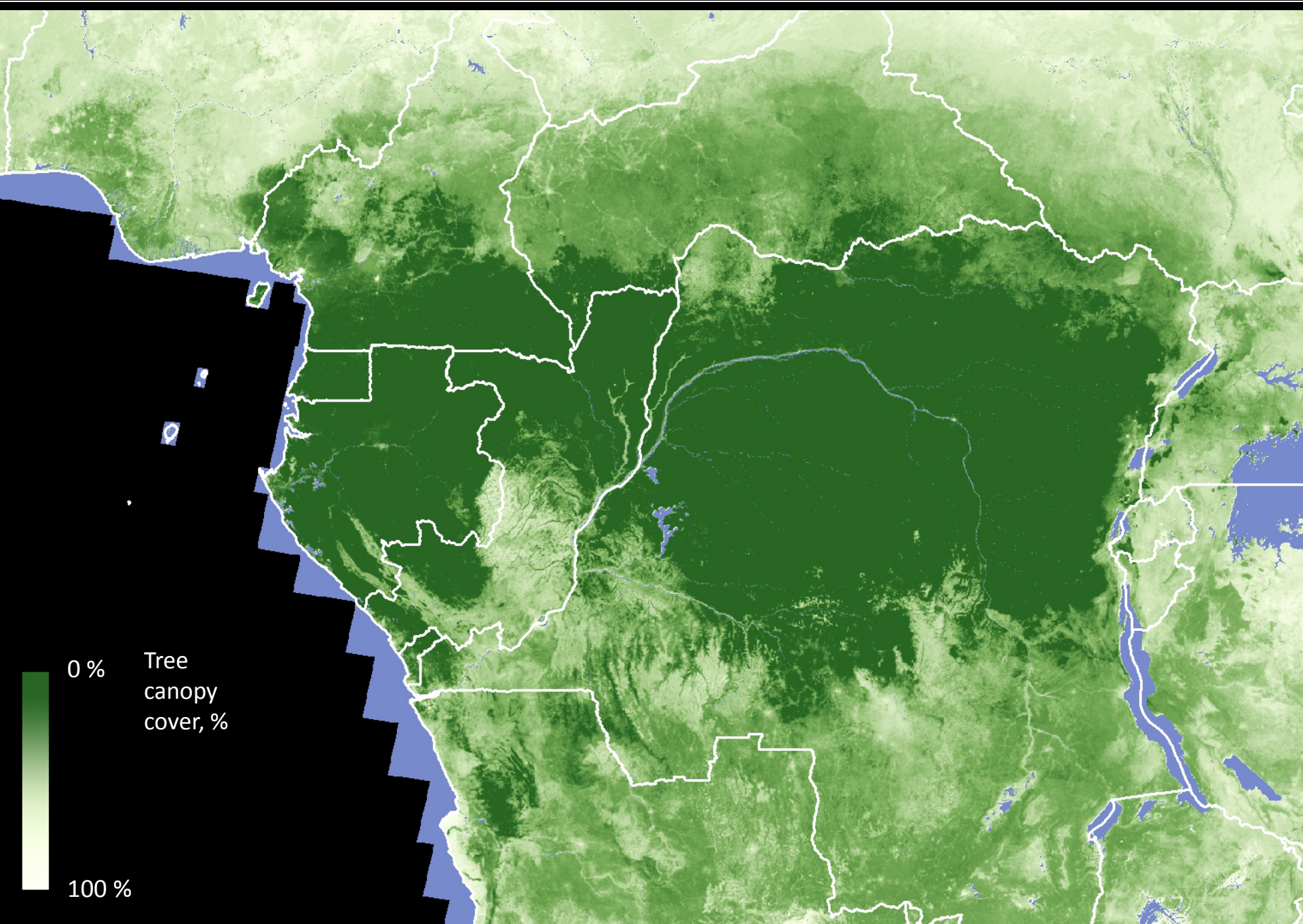


IFL Loss in the Tropics: Congo Basin



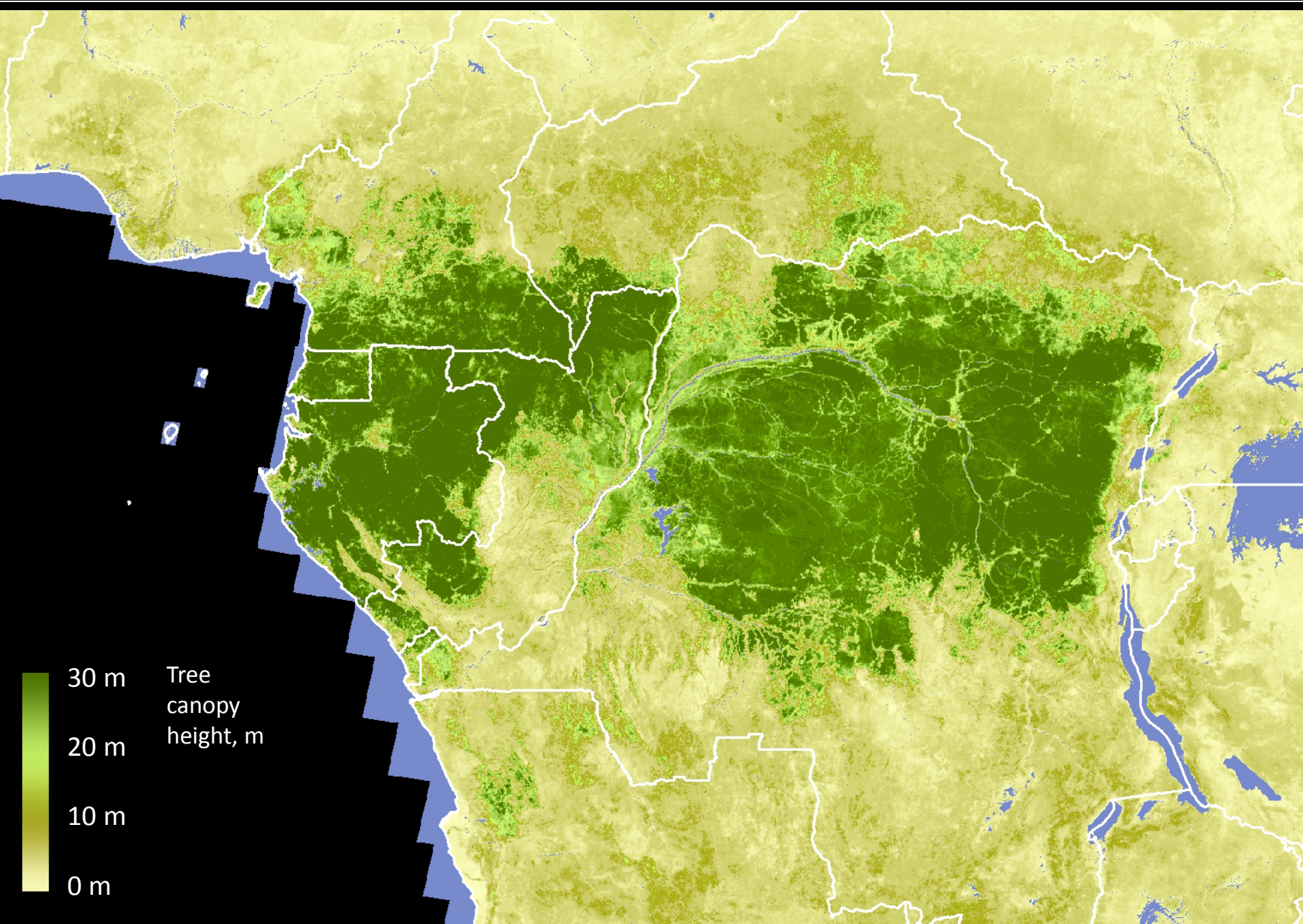
Central Africa

Tree canopy cover, 2000



Central Africa

Tree canopy height, 2000

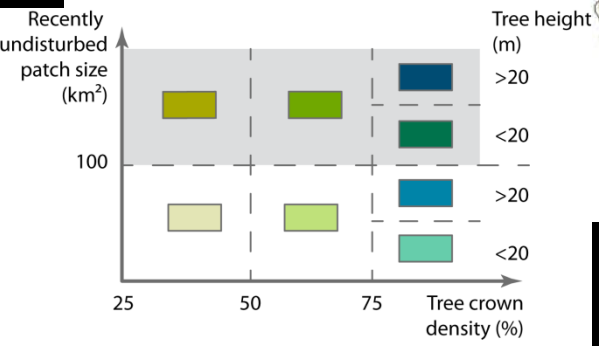


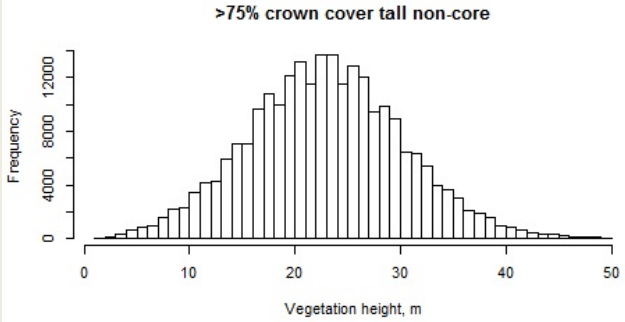
Central Africa

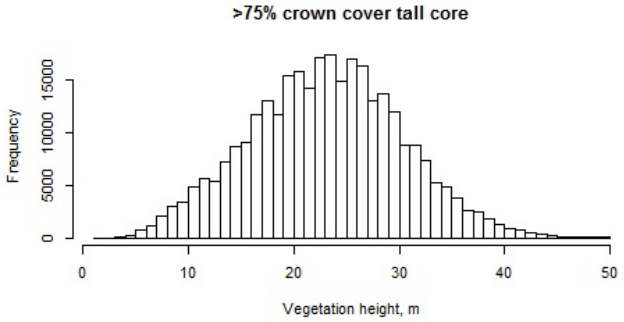
Forest cover loss, 2000 to 2012

Central Africa

Intact Forest Landscape 2.X




>75% crown cover tall non-core
Frequency
0
4000
8000
12000
0
10
20
30
40
50
Vegetation height, m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Frequency
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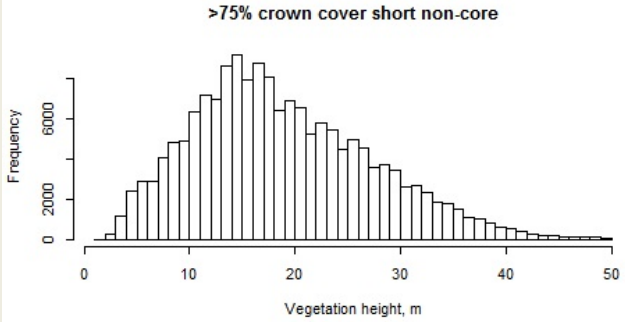
0
10
20
30
40
50
Vegetation height, m


>75% crown cover short non-core
Frequency
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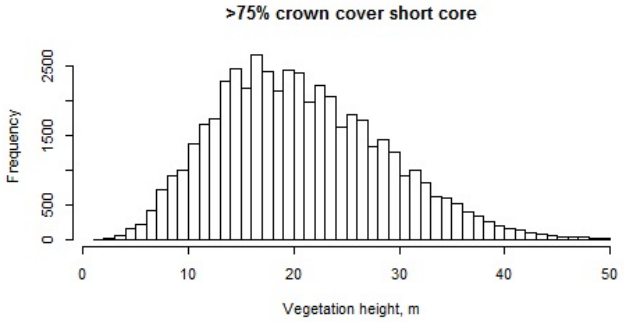
2000
6000
0
10
20
30
40
50
Vegetation height, m


>75% crown cover short core
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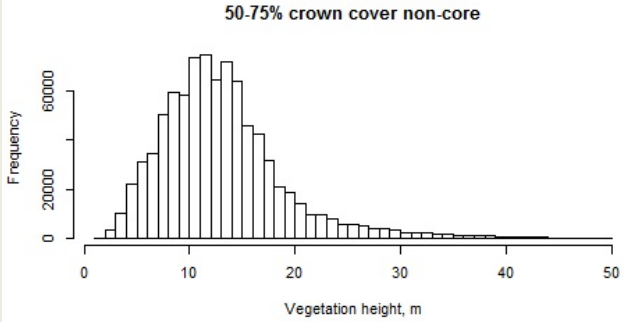
500
1500
2500
0
10
20
30
40
50
Vegetation height, m


50-75% crown cover non-core
Frequency
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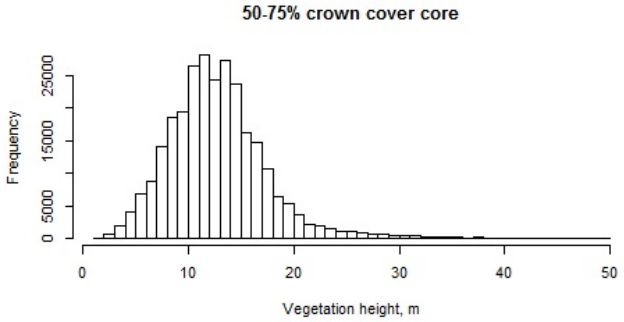
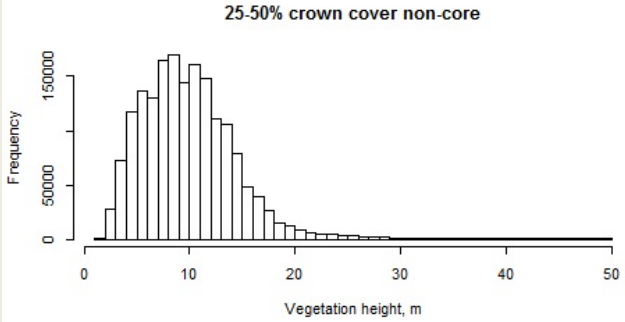
20000
60000
0
10
20
30
40
50
Vegetation height, m


50-75% crown cover core
Frequency
0
5000
15000
25000
0
10
20
30
40
50
Vegetation height, m


25-50% crown cover non-core
Frequency
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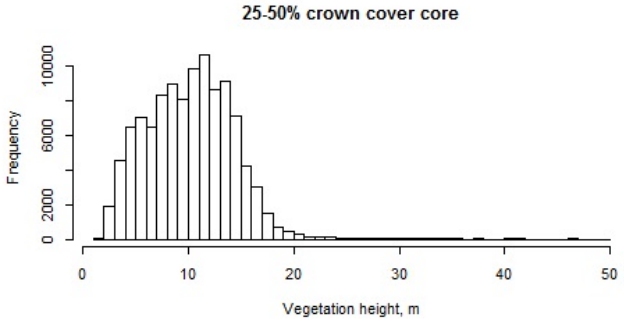
50000
150000
0
10
20
30
40
50
Vegetation height, m


25-50% crown cover core
Frequency
0
2000
6000
10000
0
10
20
30
40
50
Vegetation height, m

Estimating aboveground biomass loss

Approaches to mapping and monitoring carbon stocks (Goetz & Dubayah, 2011):

- "Stratify and Multiply"
- "Combine and Assign"
- "Direct Remote Sensing"

Basic IPCC equation to calculate carbon emissions (IPCC, 2006, vol.1, ch.1.2):

*Emissions = AD * EF*

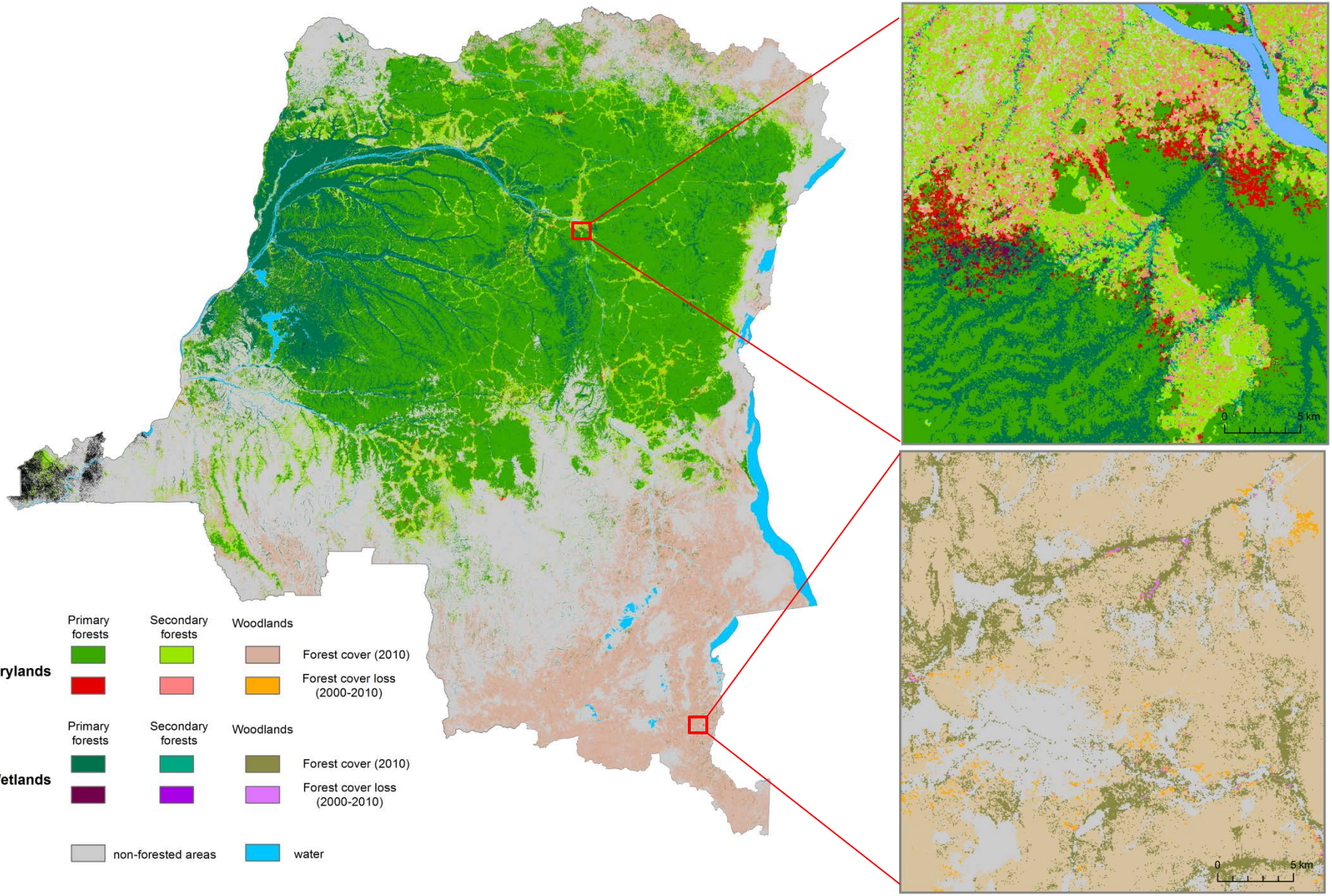
AD – activity data, the extent of human activity
EF – quantifies emissions of removals per unit activity

Assessment of uncertainties needed for both AD and EF

AD:

- published datasets often don't have extensive accuracy information;
- areas of low accessibility -> direct field validation is expensive/not feasible

Data: Activity data



Methods: validation of activity data

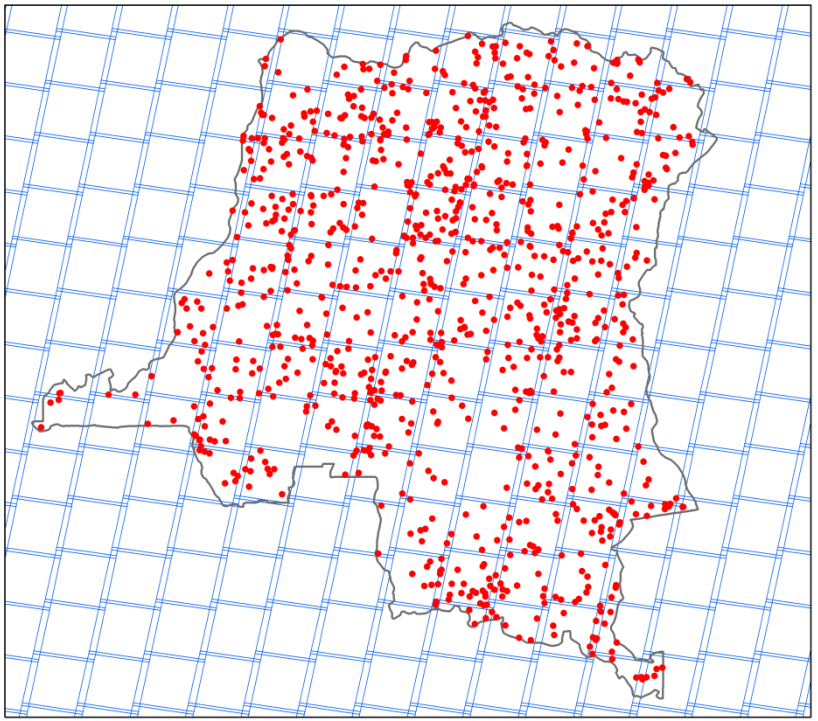
Primary objective – estimate error-adjusted area of forest cover loss within each forest type (Olofsson et al., 2013)

Sampling design:

- Stratified random sampling
- Allocation of samples among strata -> arbitrary, between equal and proportional, to account for both committed and omitted loss area
- National-scale land cover product is conservative, tends to omit loss ->
  -> additional “no loss – probable loss” stratum to better estimate omitted loss area

Allocation of validation samples (1000 60-m FACET pixels)

	No loss	Probable loss	Loss	Total
Primary forest	200	70	63	333
Secondary forest	30	87	50	167
Woodlands	100	90	60	250
Swamp primary forest	80	30	57	167
Swamp secondary forest	15	15	12	42
Swamp woodlands	15	15	12	42



Validation data:

- original 30-m Landsat images (2000 and 2010),
- high resolution imagery from Google Earch and CARPE archives (available for 484 samples)

Data: Biomass data

GLAS-predicted biomass (Baccini et al., 2012):

Regression model (explains 83% of variance in field AGB measurements):

*AGB = - 31.631 + 15.952 * HOME * + 7.832 * H10 – 18.805 * H60 –*
*– 38.428 * CANOPY_ENE + 8.285 * H25*

H10, H25, H60	height in the waveform, where the given energy percentile is reached
HOME	the height of median energy
CANOPY_ENE	the integral of the function between signal beginning and the top of ground peak

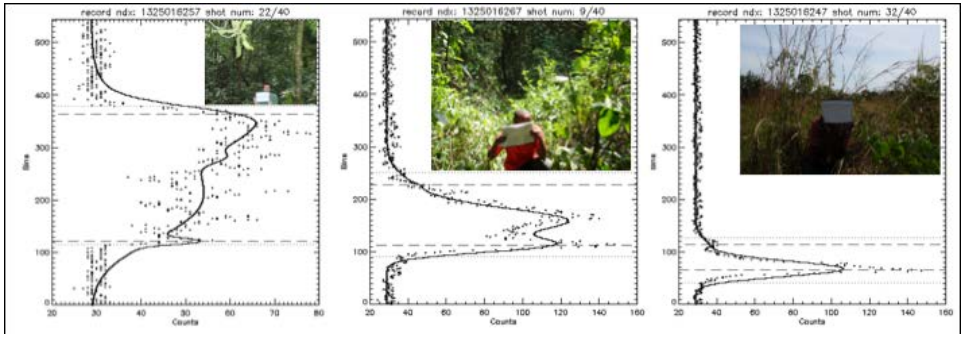
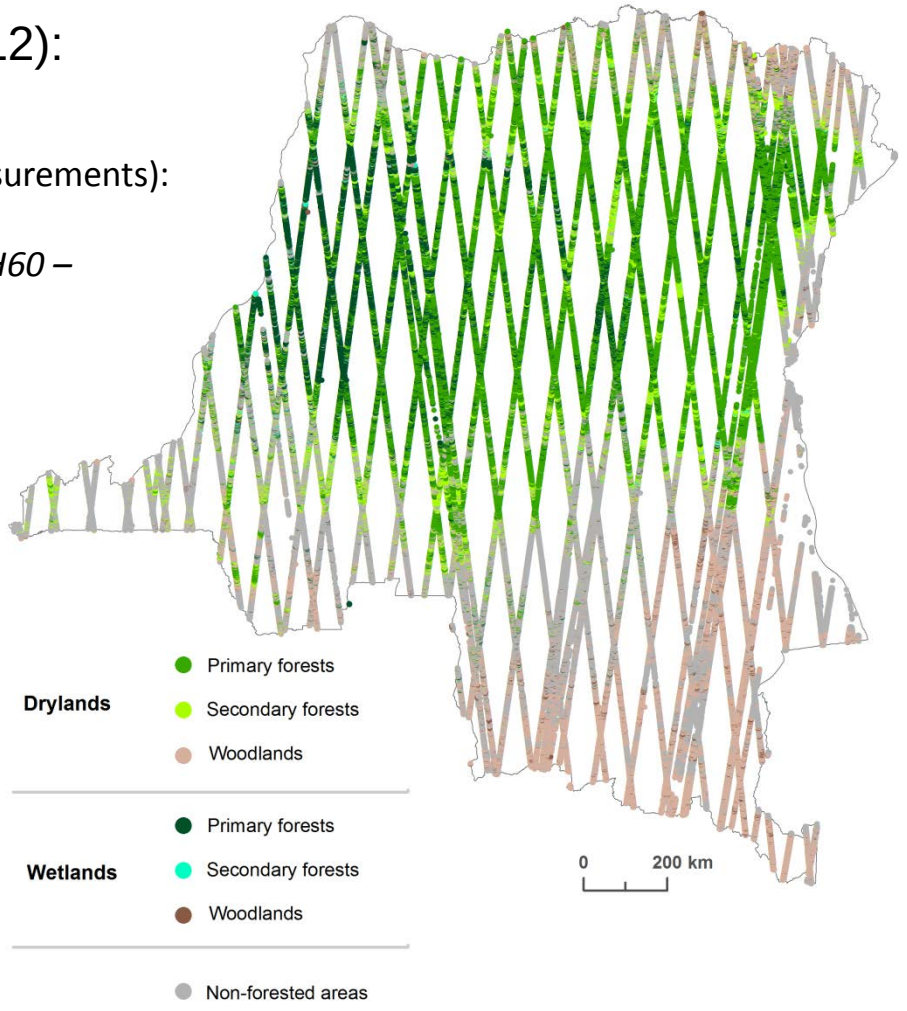
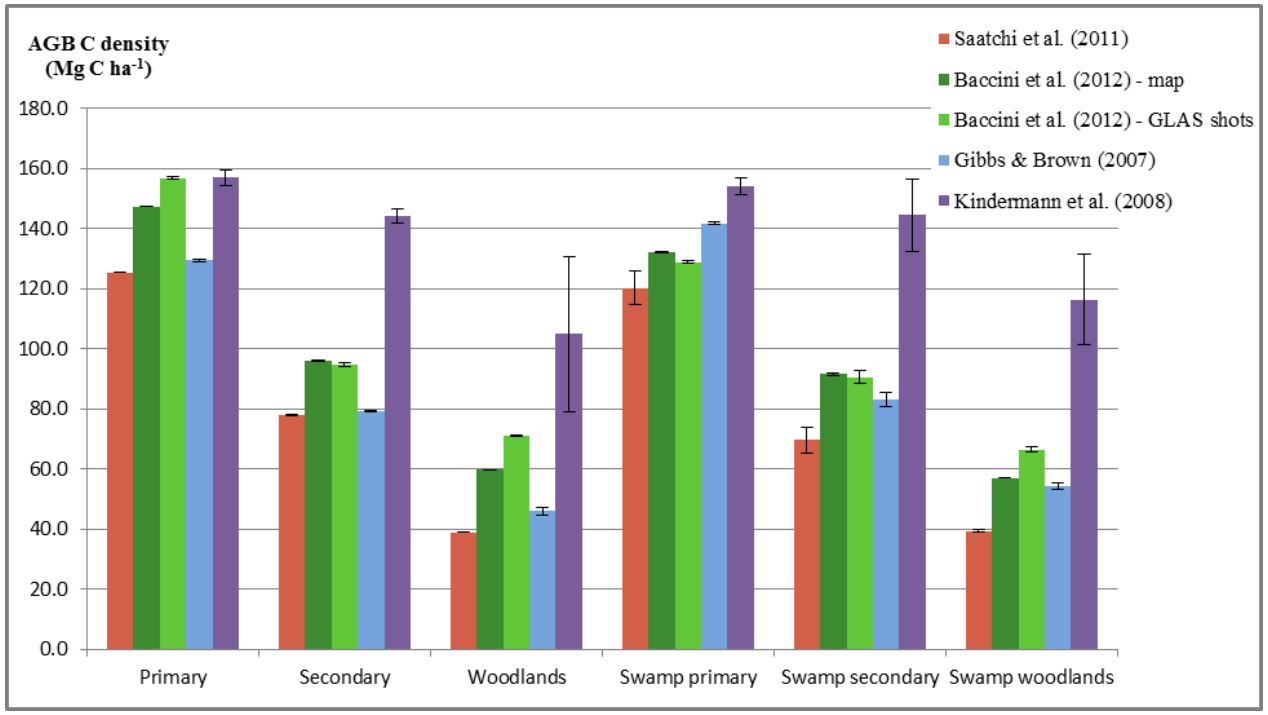


figure from *Baccini et al., 2012*



Data: Biomass data

Forest type	Mean AGB carbon density (Mg C ha^{-1})	№ of GLAS samples	STD	SEM
Primary forest	156.83	115566	67.03	0.20
Secondary forest	94.79	31443	67.45	0.38
Woodlands	71.21	121671	44.24	0.13
Swamp primary forest	128.86	85923	55.29	0.19
Swamp secondary forest	90.67	3148	65.83	1.17
Swamp woodlands	66.52	13707	45.81	0.39



Methods: combining uncertainties

IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006, vol.1, ch.3):

- ***multiplication approach*** ← *AGB loss = ΔAD * Biomass*

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

U_{total} - the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as percentage);
U_i - the percentage uncertainties associated with each of the quantities.

Forest type	U_{AD} (%)	$U_{Biomass}$ (%)	U_{total} (%)
Primary forest	20.02	0.13	20.02
Secondary forest	11.32	0.40	11.33
Woodlands	27.98	0.18	27.98

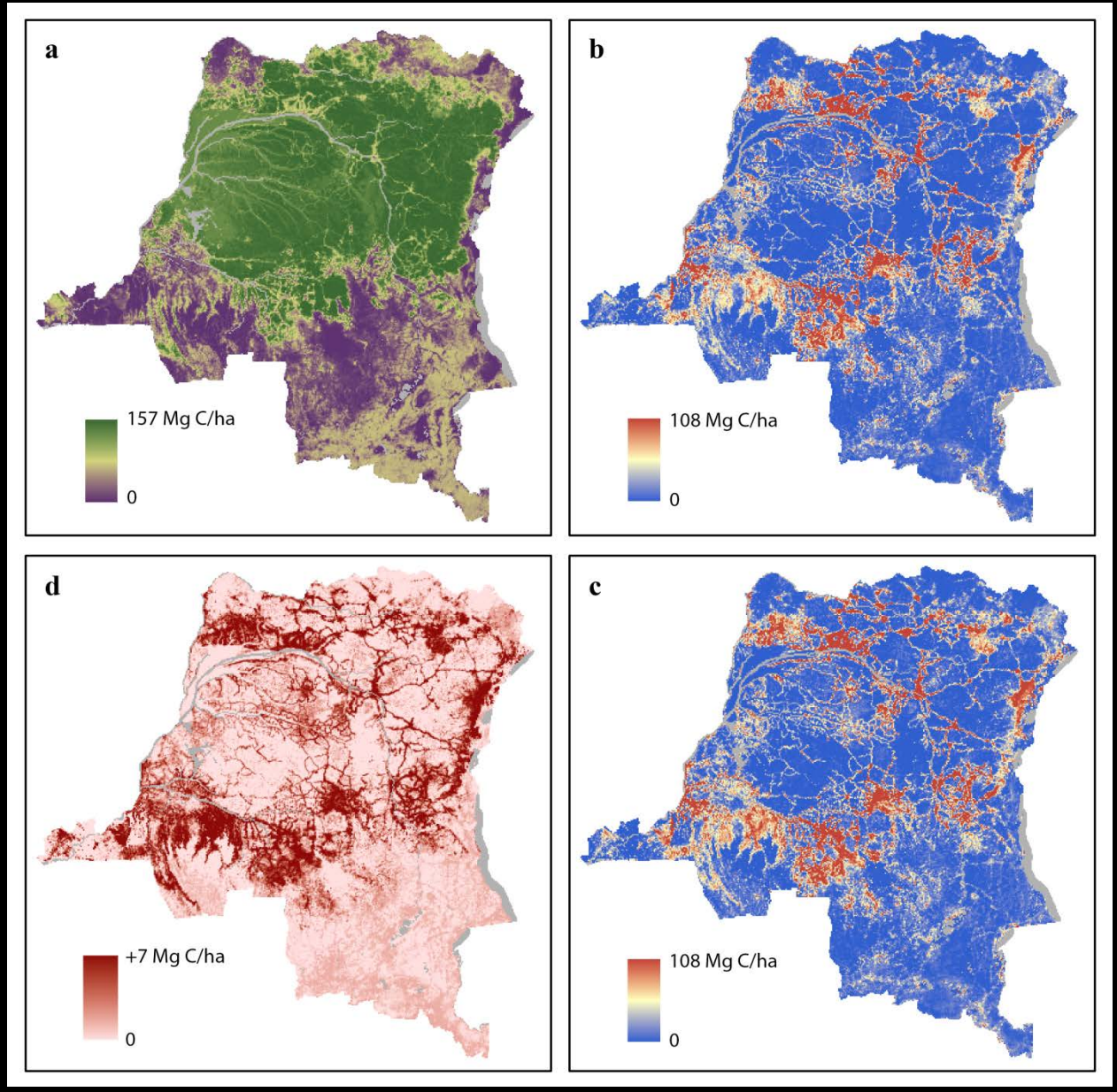
Forest type	U_{AD} (%)	$U_{Biomass}$ (%)	U_{total} (%)
Swamp primary forest	5.79	0.15	5.79
Swamp secondary forest	45.52	1.29	45.54
Swamp woodlands	13.48	0.59	13.50

- ***addition and subtraction approach*** ← *Total DRC AGB loss = Σ*

$$U_{total} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{|x_1 + x_2 + \cdots + x_n|}$$

x_i **and** U_i - the uncertain quantities and percentage uncertainties associated with them.

$Total\ DRC\ AGB\ loss$: $U_{total} = 9.4\%$



Forest type and strata averages, aggregated to the 5-km grid: a) year 2000 mean AGB; b) map-scale estimate of 2000-2010 gross AGB loss; c) sub-grid estimate of 2000-2010 AGB loss; d) difference between sub-grid and map-scale estimates. Water bodies area shown in grey.

Summary

- Large area land cover extent and change monitoring is enabled through high quality data, user-focused data management and progressive data policies
- Automated methods are required for improved spatio-temporal characterizations, but also reduced latency in product delivery
- Combining good data and advanced methods, leapfrog-like advances in mapping capabilities are enabled
- For Central Africa, spatial scale is a more critical limitation as indicated by our first FACET validation
  - In the end, Landsat may be more like MODIS, used as an indicator product with very high spatial resolution providing area estimation
- A whole host of other applications are ready to be implemented at Landsat scale
  - Agricultural/swidden system monitoring
  - Settlement/population estimation
  - Biodiversity/habitat health assessments
  - Human health and land cover integration
  - Carbon and hydrological cycle model calibration

CARPE III plans

- Regional and national forest cover types, annual forest cover loss, gain and near-real time disturbance alarm
- Primary forest stratification suitable for carbon stock assessment
- Annual forest aboveground carbon loss estimates for Central Africa at national and sub-national scales.
- Forest cover change validation with time-series high spatial resolution imagery
- Satellite derived thematic data of forest cover extent and loss for 1990-2000 for the Central Africa where feasible

CARPE III plans

- Land use intensity assessment for the rural complex in DRC
- Relating land cover resources and change to human health survey data for the DRC
- Regional scale habitat health assessment for selected species
- Landsat-derived human settlement map for improved spatial allocation of population data
- Congo River basin hydrological modeling of land use scenarios

CARPE III plans

- In-region capacity building through *Observatoire Satellital des Forêts d'Afrique Centrale* (OSFAC), regional universities and government institutions
  - Technical oversight and backstopping of OSFAC in geospatial and remote sensing applications and training, particularly in porting mapping and monitoring methods to the respective agencies in the DRC and RoC; assistance in the development of long-term sustainability plans
  - Continue research and graduate study exchanges with in-region institutions
- State of the Forest reporting
- CARPE website, data portal, web mapping services and information management tool
- Satellite data clearinghouse

Questions?