WAGENINGEN UNIVERSITY
ENVIRONMENTAL SCIENCES

SarVision

Progress on radar processing

Joint UN-REDD GEO Workshop on Measurement Reporting and Verification



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UN-REDD/GEO workshop 23.06.2010

Guadalajara, Mexico

Wageningen University

Long-term research radar satellite monitoring tropical forest, training of staff tropical forest countries

SarVision

Unit for systematic operational monitoring implementation and consistent time-series production

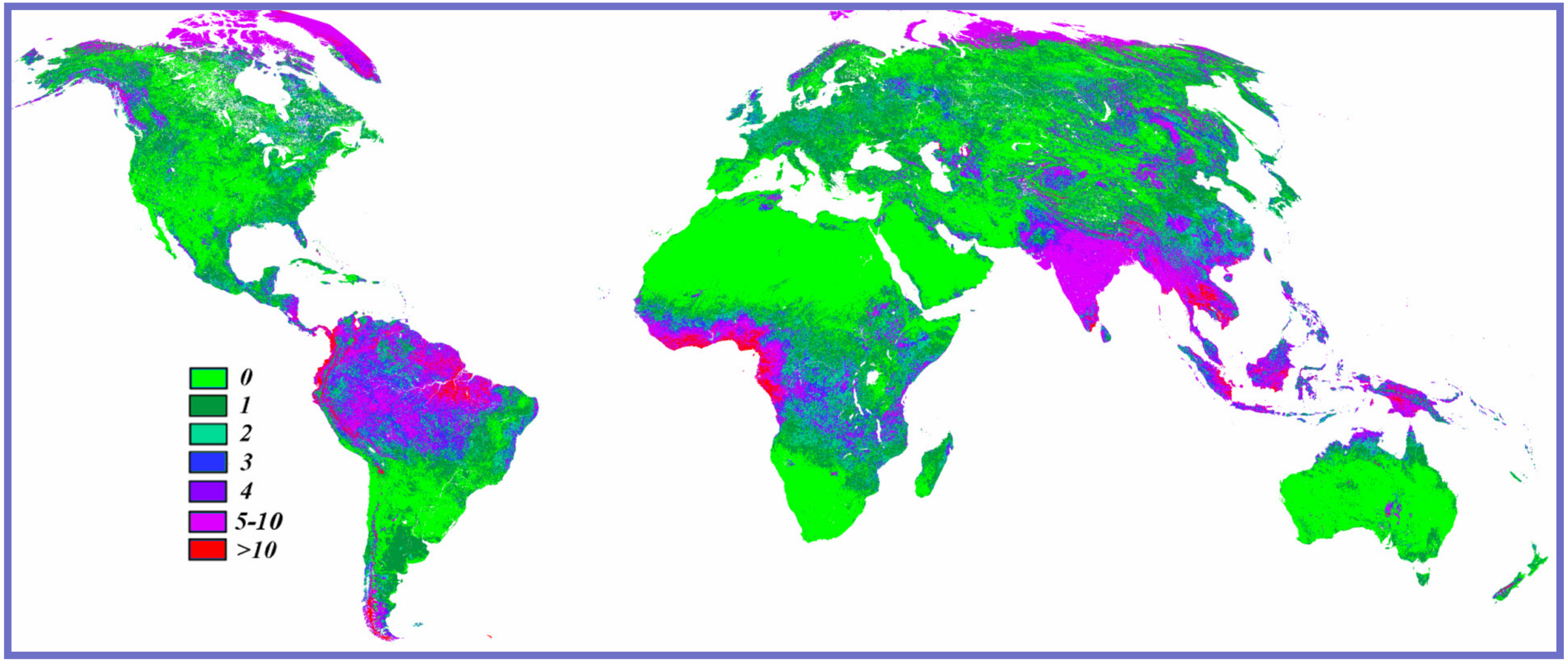
Current focus countries:

- Indonesia, Malaysia, (Papua New Guinea)
- Suriname, Guyana, Colombia, Brazil (Amapa, Para)

GEO FCT Product Development Team Borneo, Guyana

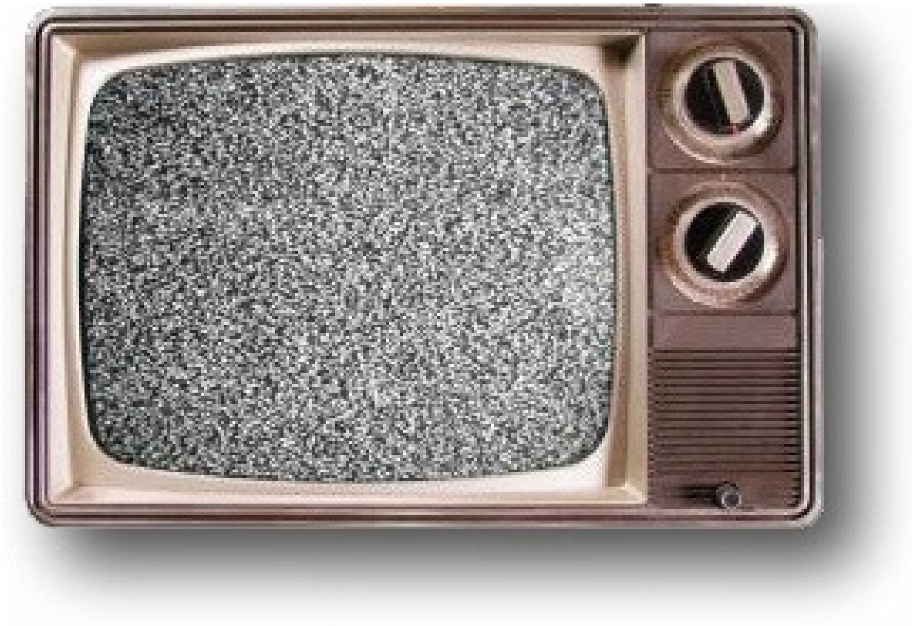
IPCC: estimates should be transparent and consistent

-> Persistent cloud cover is a big problem in tropics



Purple-red: consistent Landsat hardly possible… Friedl. Land cover recommendations, GVM workshop, August 2006

Radar in the old days, but what many people still think today…:



In the past 3 years critical improvements have been made:

- New generation radar satellites with much improved information
- New processing and radar classification techniques
- Emergence of semi-automated processing chains

Presentation outline

Wageningen Product Development team progress:

Semi-automated radar processing chain development

1. **Horizon-1 - Wide-area radar forest and land cover mapping**

   Wall-to-wall map products Borneo and Guyana

   FCT Verification Site products example Borneo

2. **Horizon-1 - Consistent radar land cover change monitoring**

3. **Progress on forest degradation monitoring using radar**

   Example: Borneo PALSAR

   Example: Guyana-Brazil TerraSAR-X

1. Forest and land cover
Wall-to-wall map products

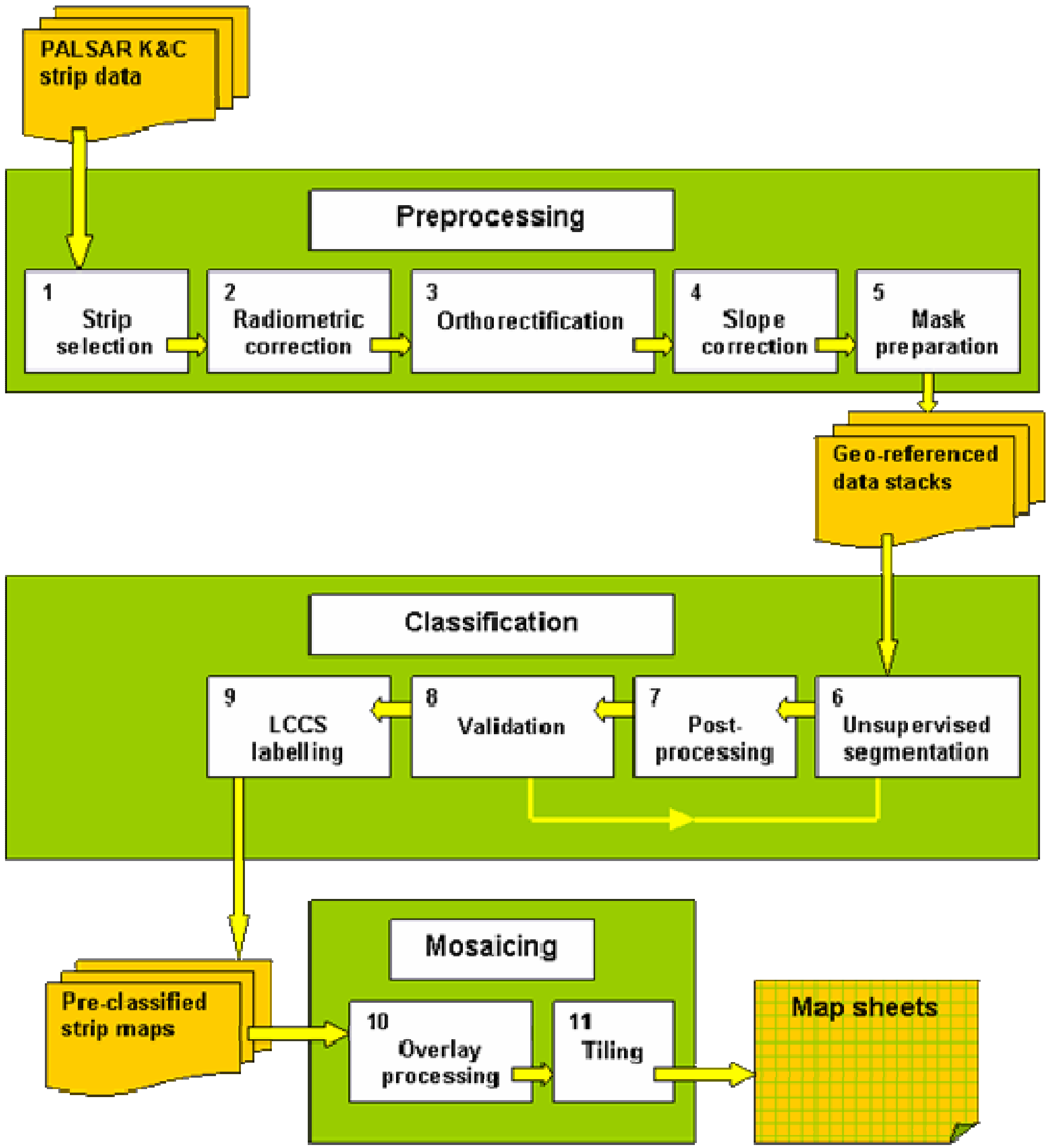
Wageningen team: Borneo, Guyana

1. Wide area land cover methodology: processing chain

Operational processing chain has been developed for systematic mapping of:

- **Forest - non-forest**
- **Land cover (LCCS)**

using ALOS PALSAR FBS and FBD strip data



1. Wide area land cover methodology: processing chain

Key features of the PALSAR methodology developed:

1) Data required: **two observations per year**, **dual polarised** data required for best results (exploit extra information due to differences in **wet and dry season** for identification of wetlands and cropland classes);

2) **Slope correction** is critical for deriving reliable classification results;

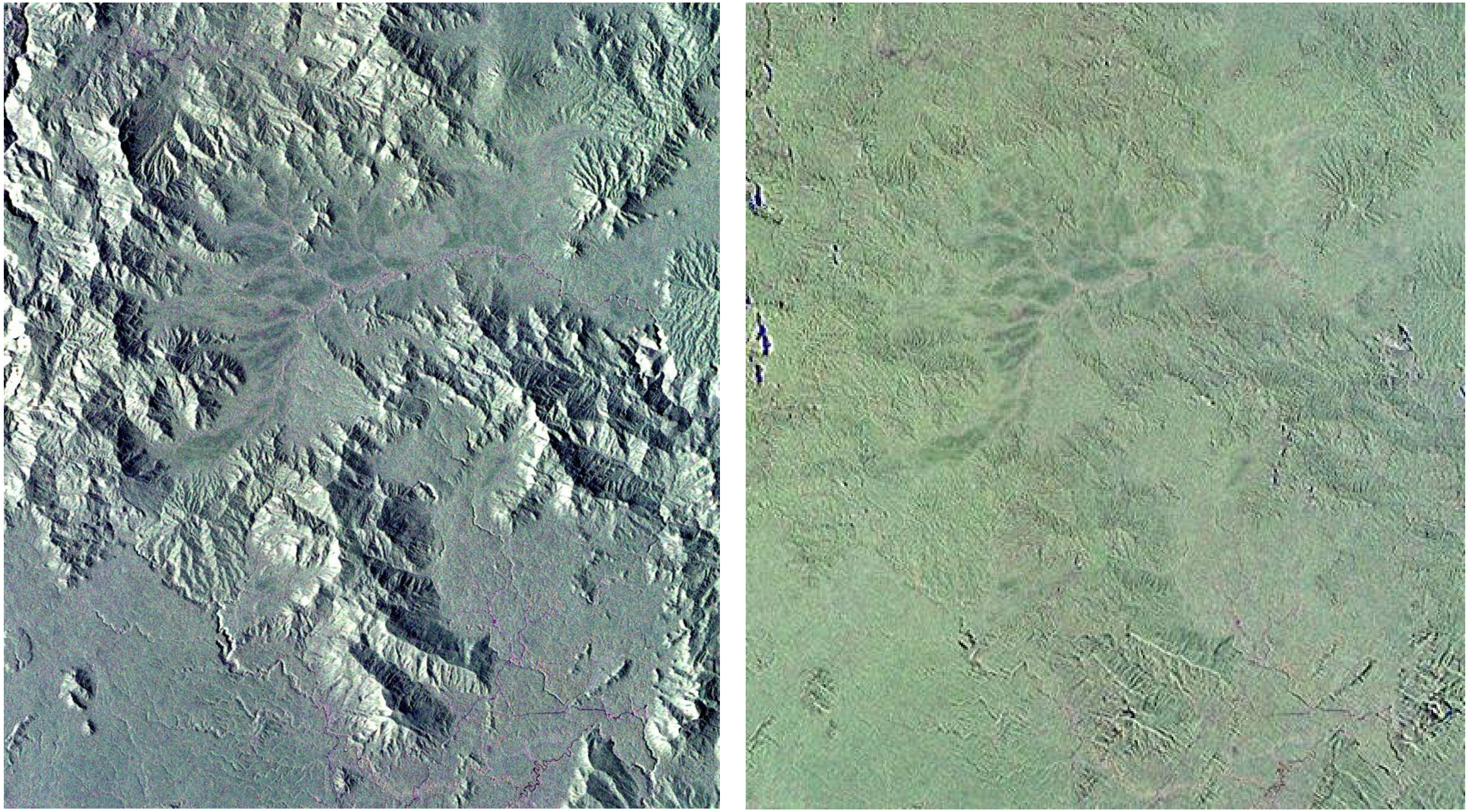
3) Optimal radar classification: best to use **probabilistic method** based on finite mixture modelling and Markov Random Fields application.

Visual interpretation does not yield acceptable results
Best methods not available (yet) in commercial software…

References:

- Hoekman, D.H., T. Tran, and M.A.M. Vissers, 2007, Unsupervised full-polarimetric segmentation for evaluation of backscatter mechanisms of agricultural crops, Proc. of POLinSAR 2007 Workshop, ESA SP-644, 22-26 Jan 2007, Frascati , Italy.
- Hoekman et al,. 2009, Unsupervised full-polarimetric segmentation of multi-temporal SAR data for agricultural crop type and growth stage assessment, IEEE J-STARS (in prep.)

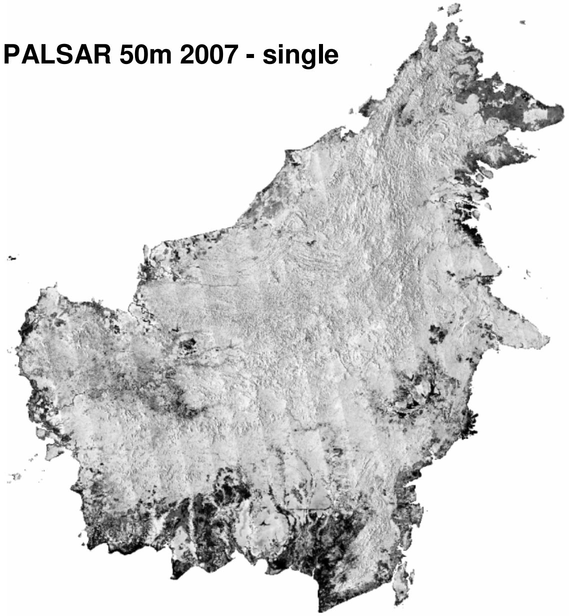
Slope correction/mitigation example



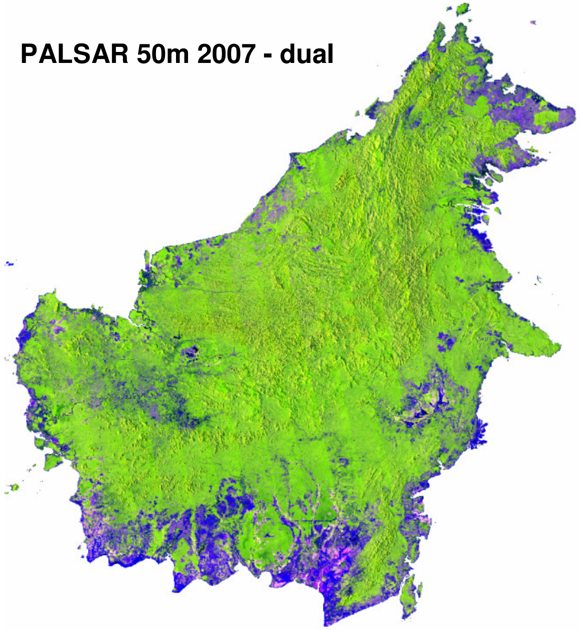
FBS/FBD composite **before** and **after** slope correction (same backscatter scale)

Example: Borneo LULC 2007: *map result*

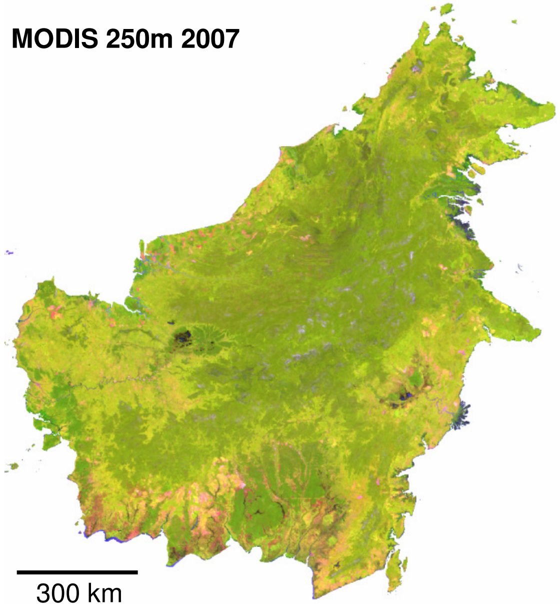
PALSAR 50m 2007 - single

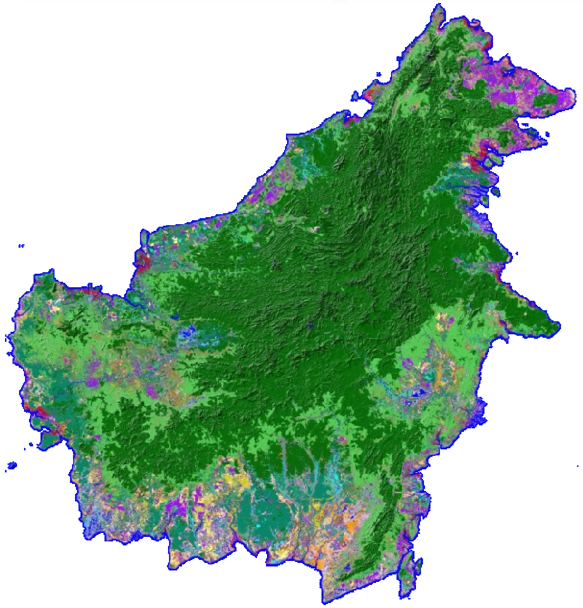


PALSAR 50m 2007 - dual



MODIS 250m 2007





Borneo LULC map used 50m PALSAR and 250m MODIS (forest regrowth)

Collaboration with local users critical for cluster selection, validation and establishing correct relation between land cover and carbon stock!

Carbon budget Central Kalimantan Peatland	
	Average estimate
Forest area	**613,000 hectare**
Carbon stock	**134,860,000 tons**

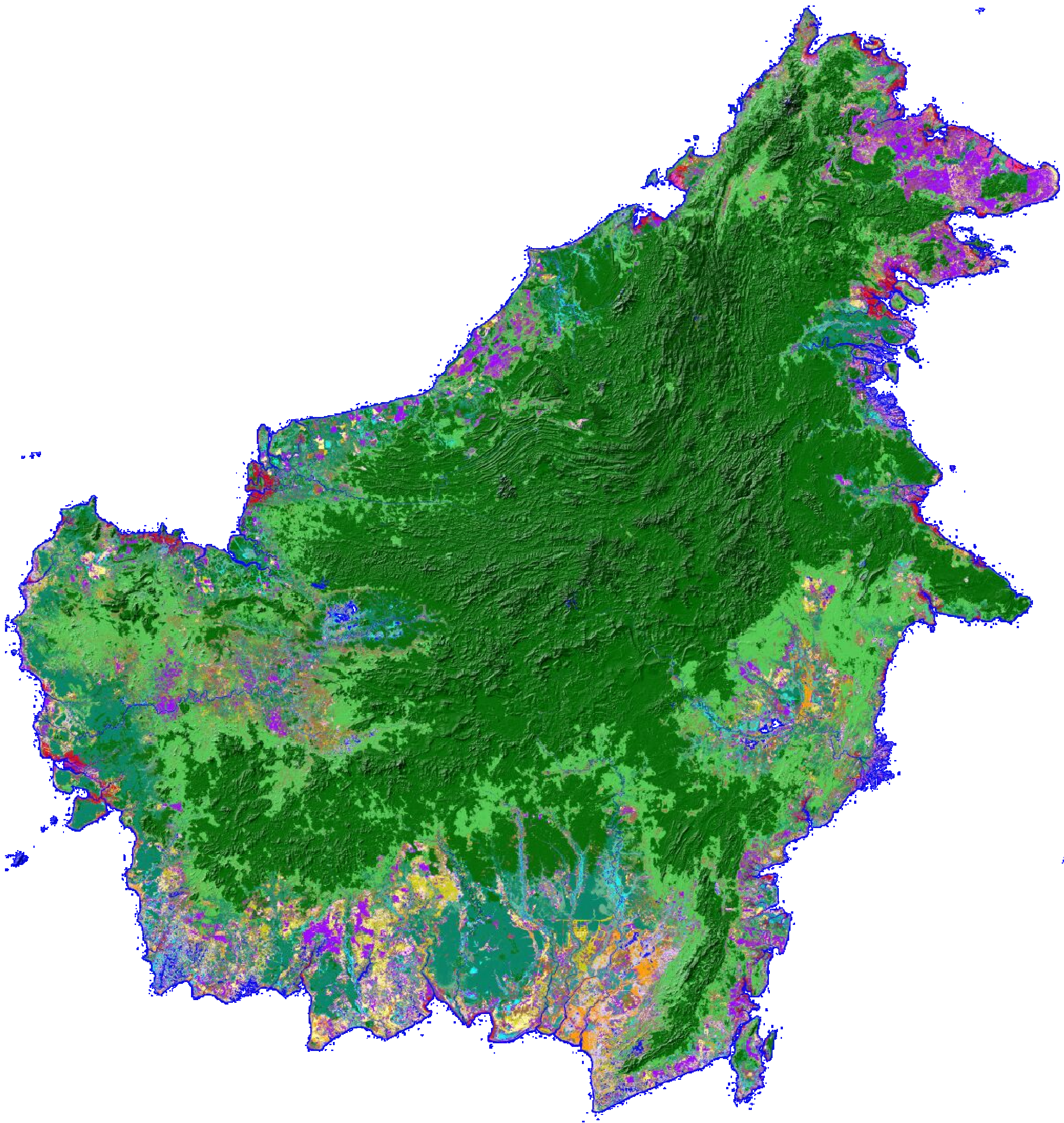
example

Example: Borneo LULC 2007: *map result*

ALOS PALSAR 2007

LULC classification Borneo

- Lowland forest
- Riverine forest
- Swamp forest
- Mangrove forest
- *Nipah* mangrove forest
- Peat swamp forest (pole)
- Peat swamp/riverine shrub
- Forest mosaics/degraded
- High shrub
- Medium shrub
- Ferns / grass
- Grassland
- Cropland (upland)
- Cropland (irrigated)
- Plantations (oil palm)
- Tree cover, burnt
- Water bodies
- Layover /Shadow
- No strip coverage
- Mountain forest



Example: Borneo LULC 2007: *10. validation*

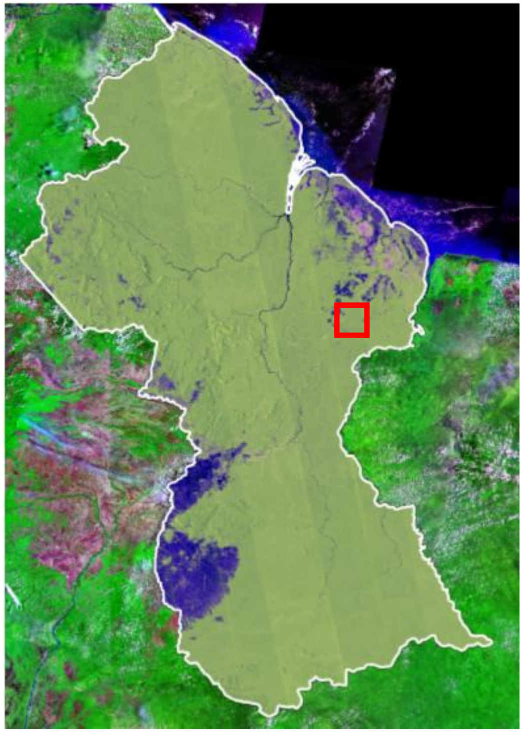
Single-year overall result: 85.5% full agreement and 7.8% 'partial agreement'.

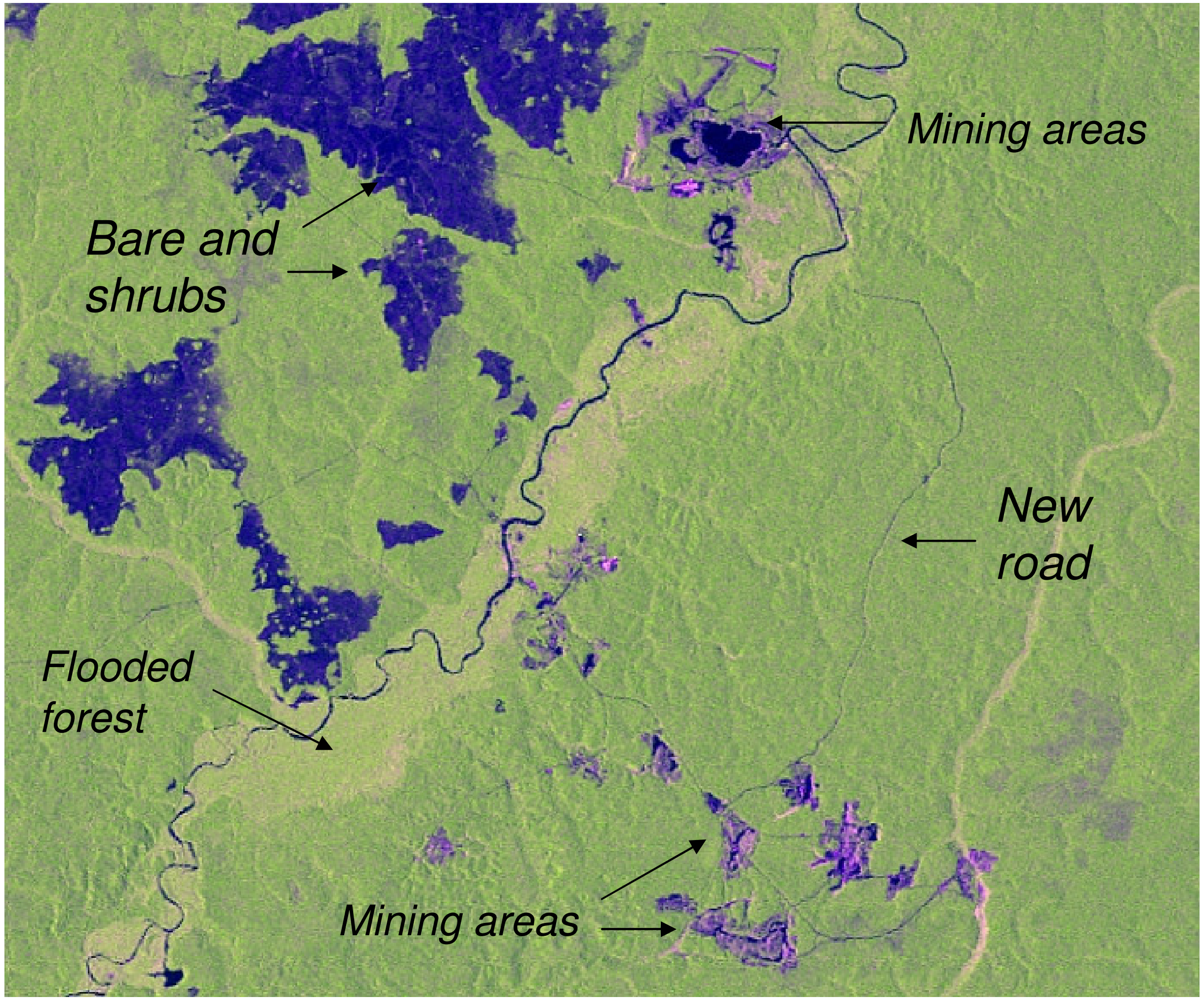
	Lowland forest	Riverine forest	Swamp forest	Mangrove forest	*Nipah* mangrove	Peat swamp forest (pole)	Peat swamp/riverine shrub	Forest mosaics/degraded	High shrub	Medium shrub	Ferns / grass	Grassland	Cropland (upland)	Cropland (irrigated)	Plantations (oil palm)	Tree cover, burnt	Water bodies
Lowland forest	99.3	0.6	0.0	0.0	0.0	15.9	0.0	73.2	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Riverine forest	0.0	58.3	0.4	0.0	0.0	1.2	0.0	0.0	0.7	15.8	0.0	0.1	0.0	0.0	0.0	7.3	0.0
Swamp forest	0.0	0.0	72.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Mangrove forest	0.0	0.0	0.0	80.1	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.4	0.0	0.0	0.0	0.0
Nipah mangrove forest	0.0	0.0	0.0	0.2	57.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Peat swamp forest (pole)	0.0	0.0	0.0	1.5	0.0	77.2	39.2	0.0	18.1	21.9	0.0	6.1	0.4	0.0	0.0	0.0	0.0
Peat swamp/riverine shrub	0.0	22.3	0.1	0.5	1.3	2.2	59.1	0.0	12.5	24.3	0.0	0.2	0.5	0.0	0.0	0.4	0.0
Forest mosaics/degraded	0.5	0.2	0.1	9.7	0.0	2.0	0.0	23.0	0.1	19.3	0.0	0.2	3.2	0.1	0.0	0.0	0.0
High shrub	0.0	0.1	0.0	5.6	1.8	0.1	1.6	0.1	27.3	6.4	0.3	0.7	22.9	0.7	0.6	0.0	0.0
Medium shrub	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	19.6	8.8	0.0	0.0	0.0
Ferns / grass	0.0	0.0	0.3	0.4	1.3	0.0	0.0	0.0	2.5	0.0	99.7	10.3	12.4	7.3	0.0	0.0	0.0
Grassland	0.0	0.0	2.8	0.1	0.0	0.0	0.0	0.0	14.2	3.9	0.0	58.0	2.0	0.2	5.6	0.0	0.0
Cropland (upland)	0.0	0.0	5.3	0.2	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	24.4	0.6	0.0	0.0	0.0
Cropland (irrigated)	0.0	0.0	2.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	78.8	0.0	0.0	0.0
Plantations (oil palm)	0.0	0.4	4.0	0.1	27.5	0.0	0.1	0.2	24.7	0.6	0.0	24.3	3.0	0.0	93.8	0.0	0.0
Tree cover, burnt	0.0	18.0	11.0	0.0	0.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	92.0	0.0
Water bodies	0.0	0.0	0.6	1.1	1.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.7	3.5	0.0	0.0	100.0
Layover /Shadow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No strip coverage	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mountain forest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Full agreement = 85,48%	Partial agreement = 7,79%	Disagreement = 4,10%	Minor confusion cases = 2,63%

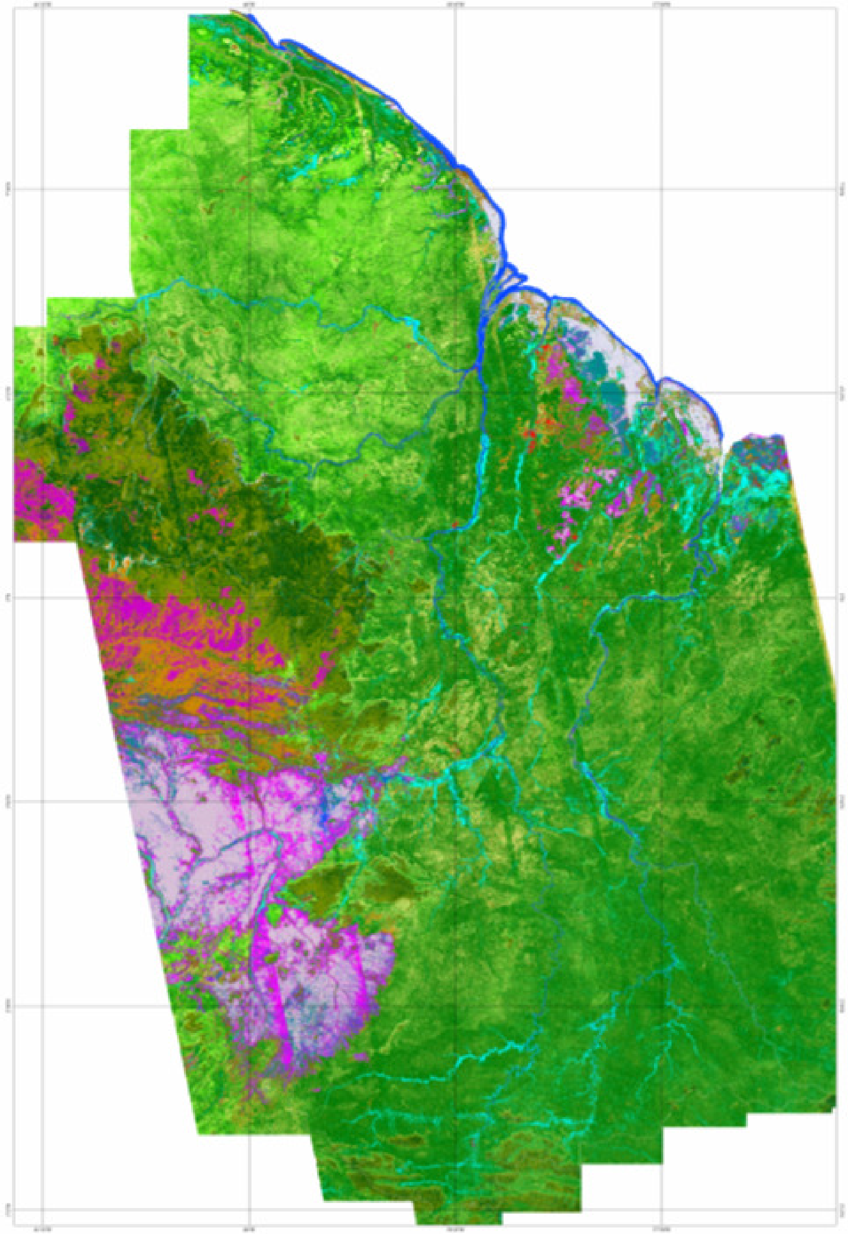
Note: bare areas and urban areas to be derived from other sensors

Example: Guyana LULC 2007: *radar data*





Example: Guyana LULC 2007: *map result*

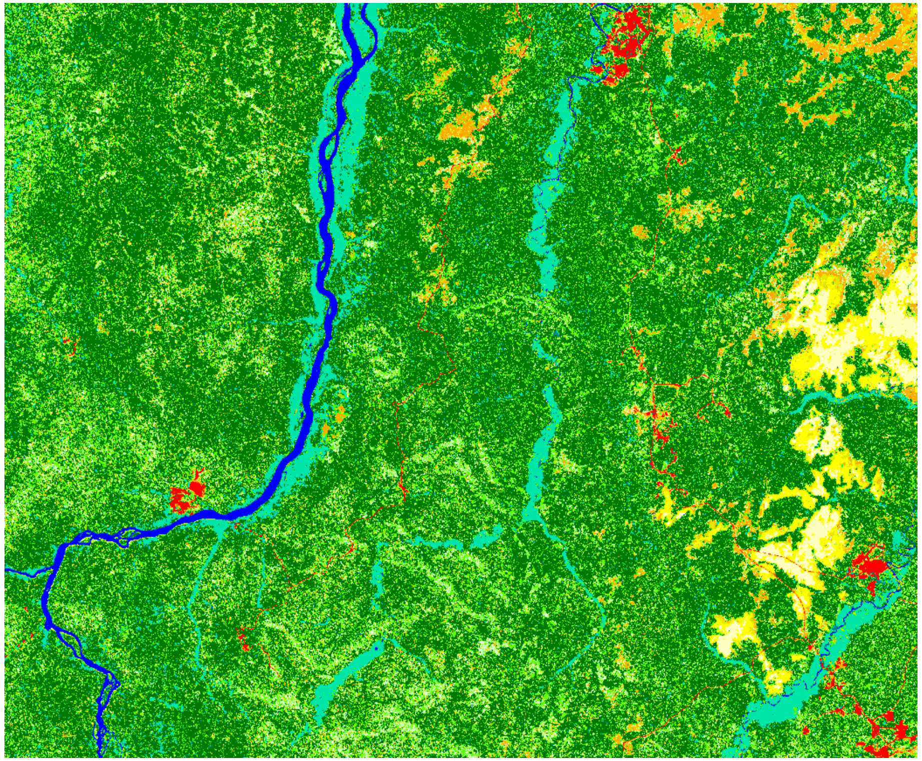


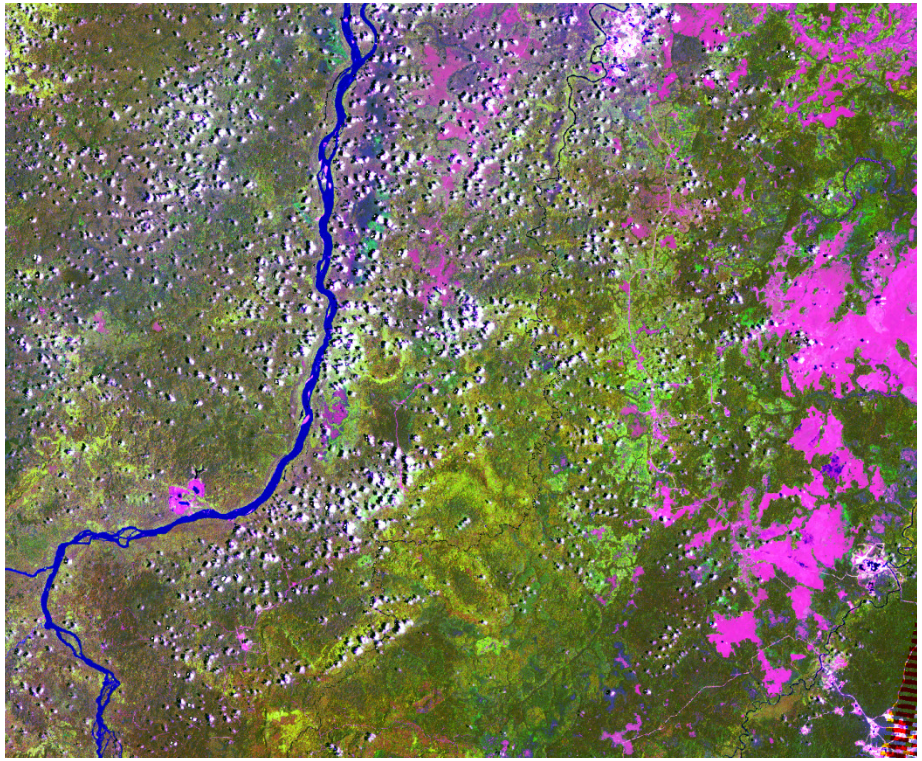
Tentative LULC map 2007

Vegetation stratification

Vegetation Type	Associated Biomass level	Map Color
Seasonally Flooded Forest	High	
Lowland Mixed forest	High	
Lowland Mixed forest	High - Med	
Lowland Mixed forest	Med	
Montane-mixed forest	High	
Montane-mixed forest	High - Med	
Lowland Shrublands	Med	
Lowland Shrublands	Med - Low	
Upland Shrublands	Med	
Upland Shrublands	Med - Low	
Lowland Savannas	Med - Low	
Lowland Savannas	Low	
Lowland Savannas	Very Low	
Upland Savannas	Med - Low	
Upland Savannas	Low	
Degraded vegetation- flooded	Med-Low	
Agriculture-	Various	
Bare	Very Low	
Water	-	

Example: Guyana LULC 2007: *map result*





Left: PALSAR vegetation type map 2007. Dark green: mixed forest high biomass, Light green: mixed forest medium biomass, Mint green: seasonally flooded forest, Orange: shrubland, Yellow: savannah, Red: bare.

Right: Landsat ETM+ 2005.

Example: Guyana LULC 2007: *map result*


Secondary regrowth


Grassland (Savanna)


Cropland (Sugar cane)


Bare areas (bauxite mine)


Lowland forest (Wallaba)


Shrubland (Mori)

Similarly to Borneo: some shrubland detection problems (slight underestimation)

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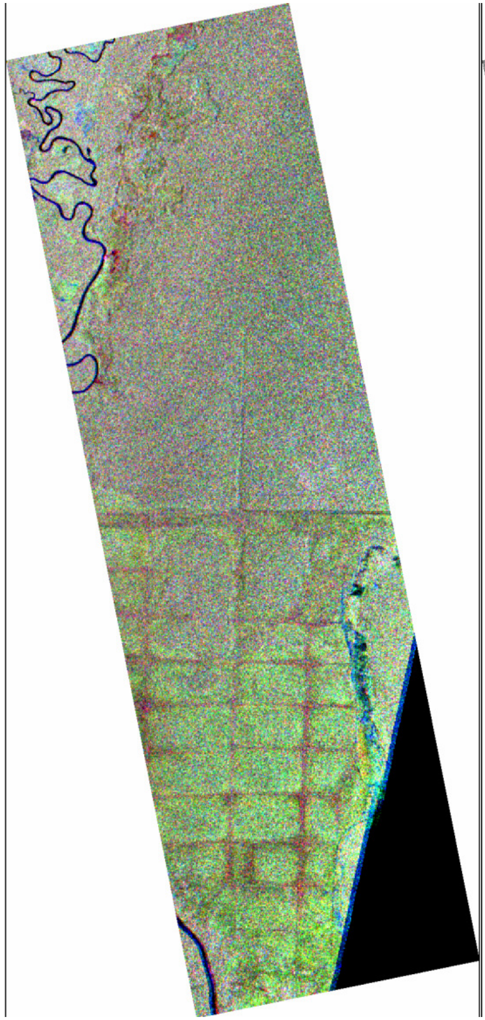
1. Forest and land cover FCT ND Verification Sites

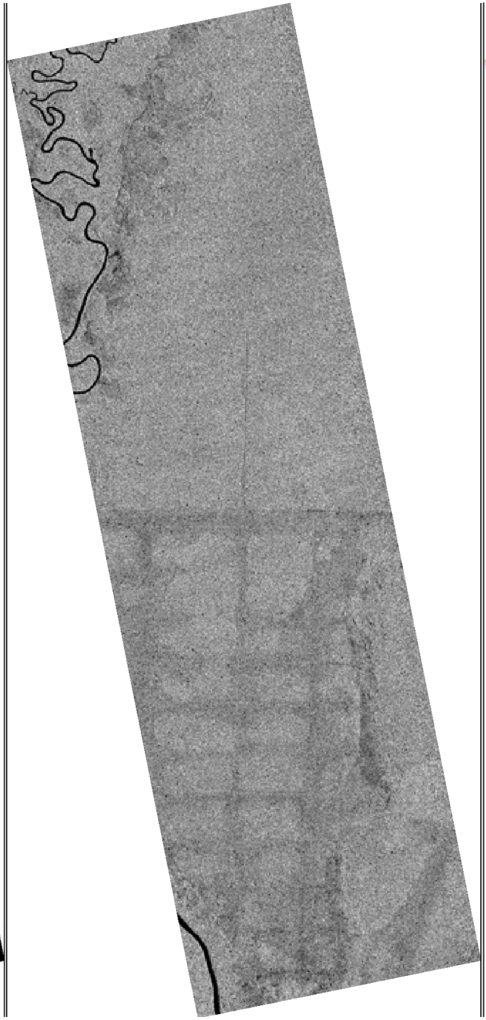
Wageningen team: Borneo, Guyana

Example Borneo BOR-3 Central Kalimantan

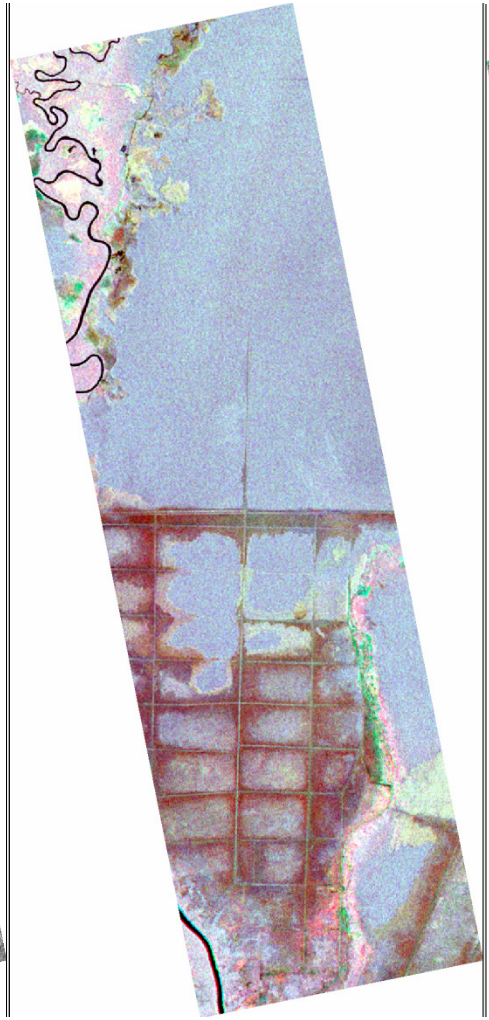
Example: ND Verification Site: *BOR-3 Central Kalimantan*



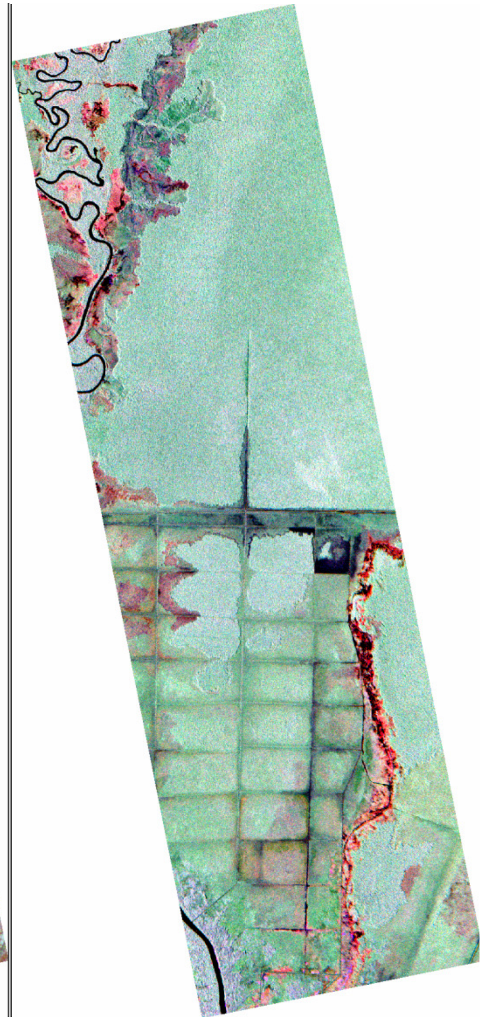
ASAR 2009



CosmoSkymed 2009

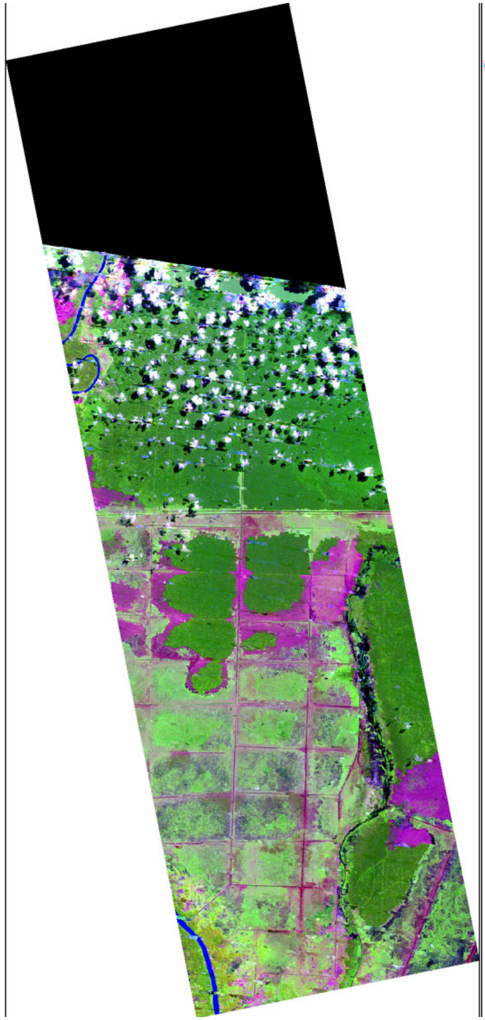


PALSAR 2009

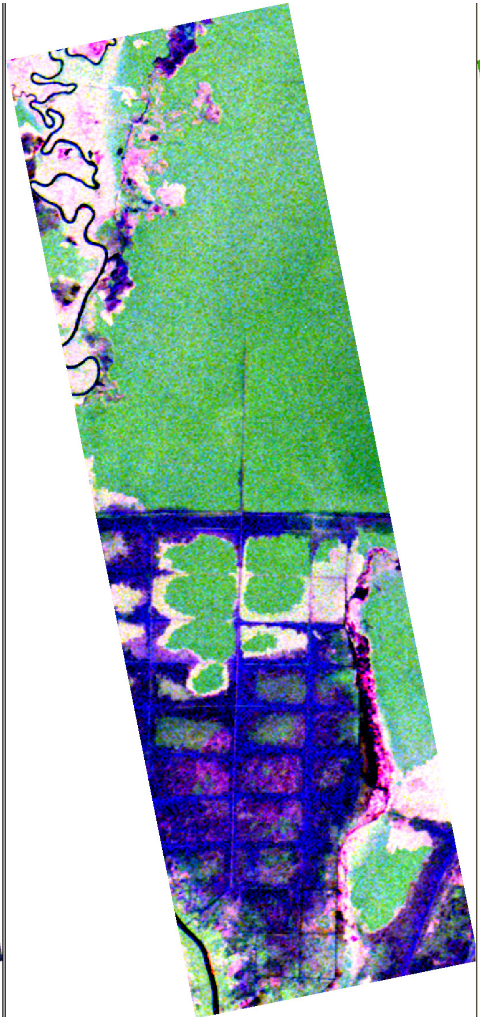


TerraSAR-X 2009

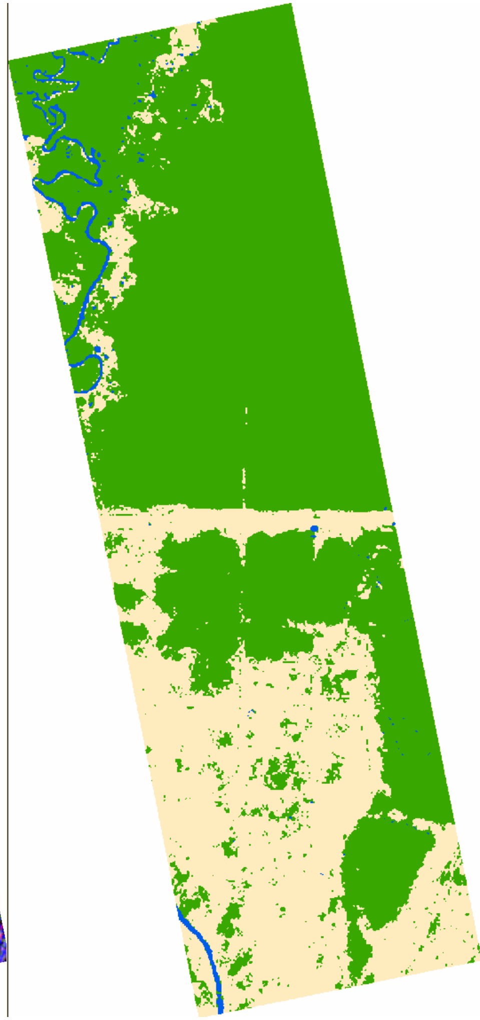
Example: ND Verification Site: *BOR-3 Central Kalimantan*



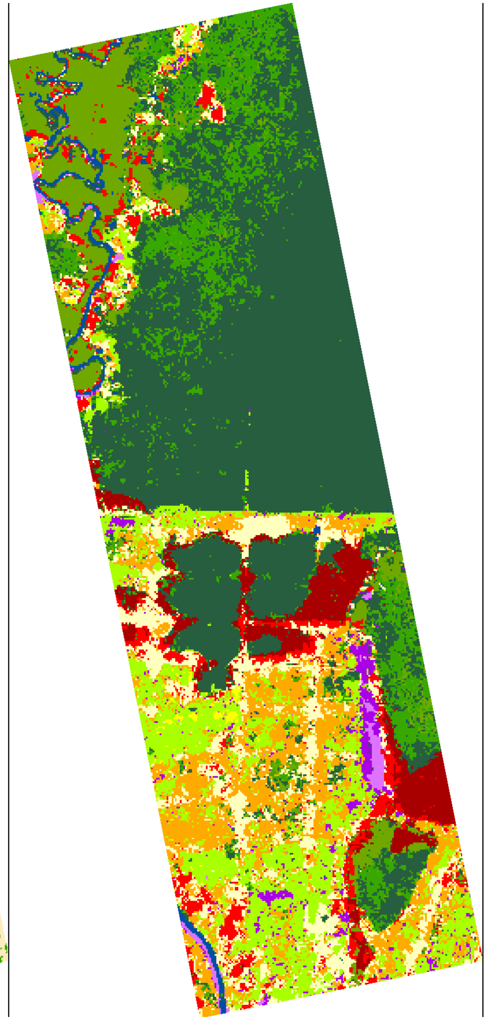
Landsat 2007



PALSAR 2007

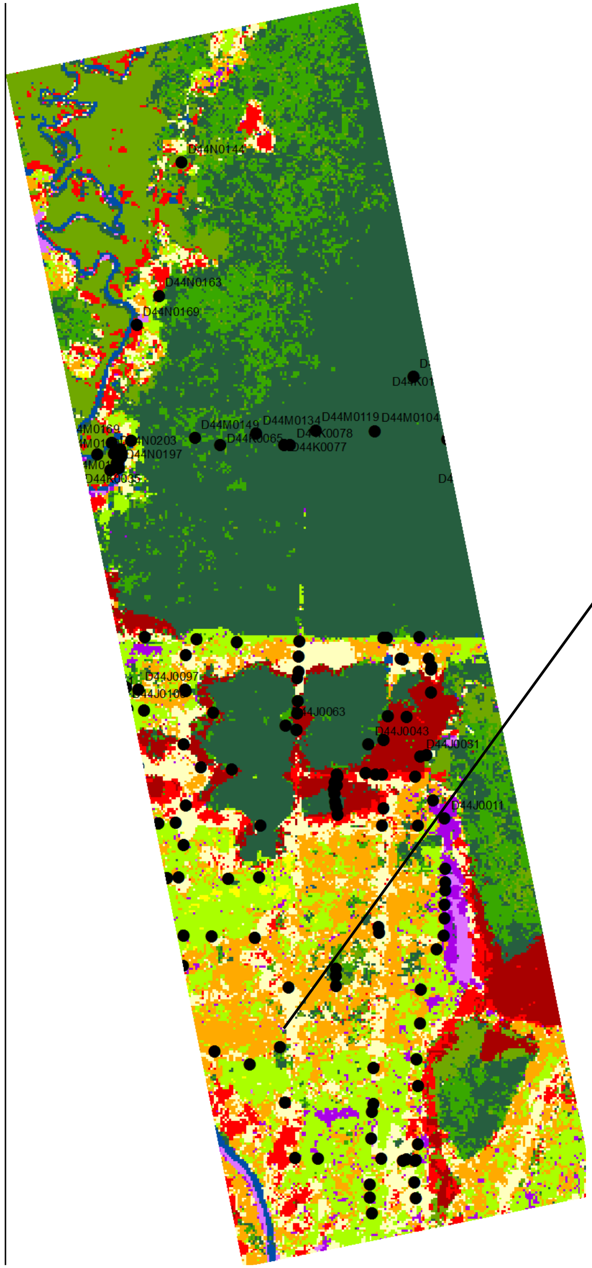


Horizon-1 FNF



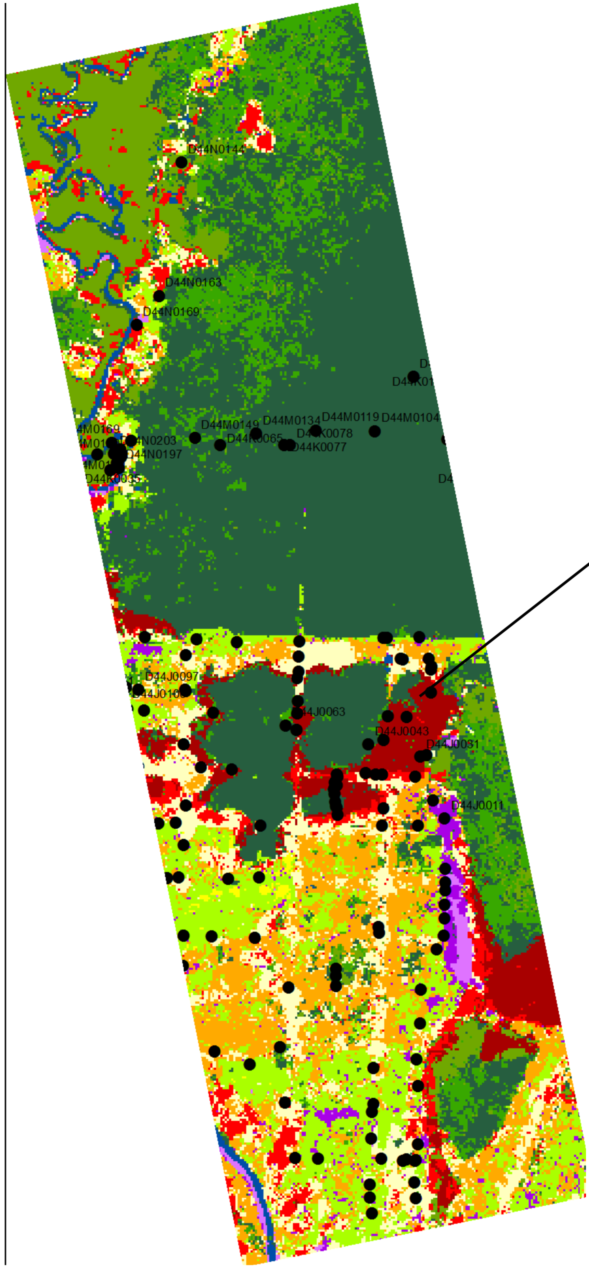
Horizon-1 LULC

Example: ND Verification Site: *BOR-3 Central Kalimantan*



- Cropland - Dry land agriculture
- Cropland - Rice paddy fields
- Forest mosaics, degraded
- Grasslands and ferns (herbaceous)
- Lowland evergreen broadleaved forest (low pole swamp forest)
- Lowland evergreen broadleaved forest (mixed swamp forest)
- Mangrove forest
- Mixed cropland and plantations
- Regularly flooded herbaceous cover (sedges)
- Regularly flooded shrub cover
- Shrub cover, burnt
- Shrubland and forest regrowth
- Swamp forest and woodland (riverine)
- Tree cover, burnt
- Urban
- Water bodies

Example: ND Verification Site: *BOR-3 Central Kalimantan*



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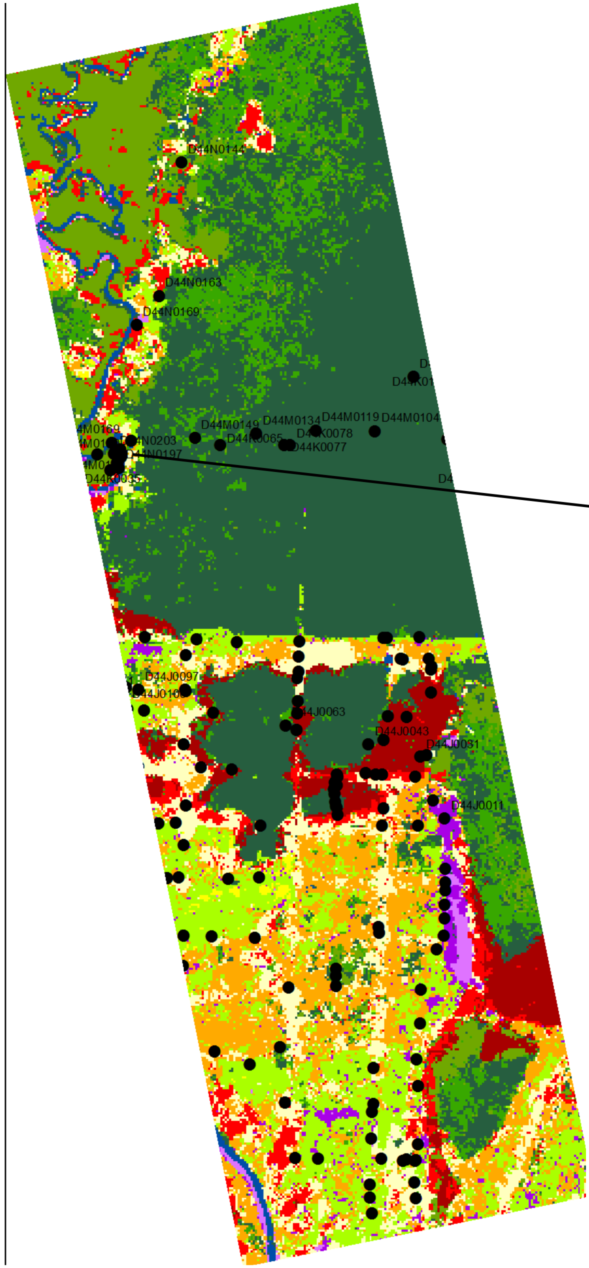

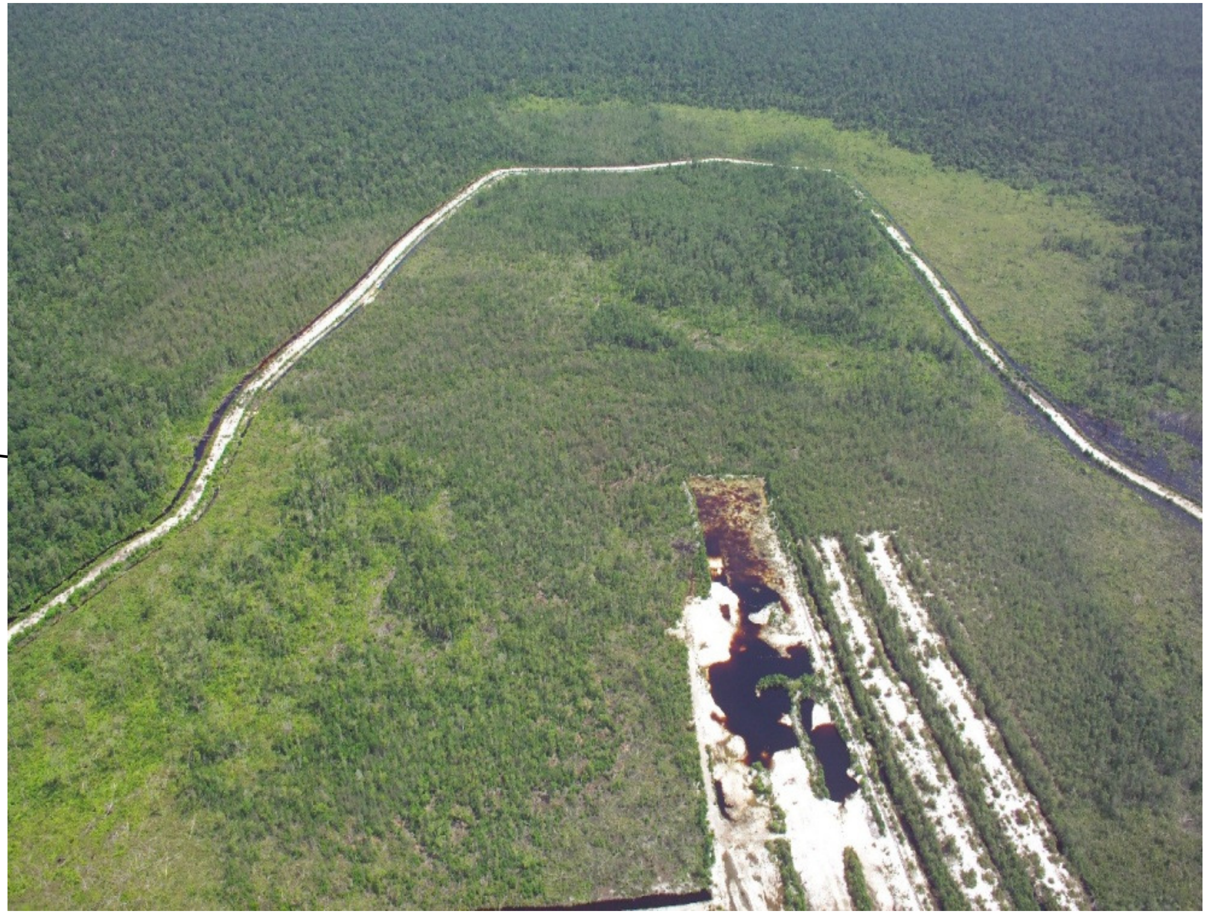

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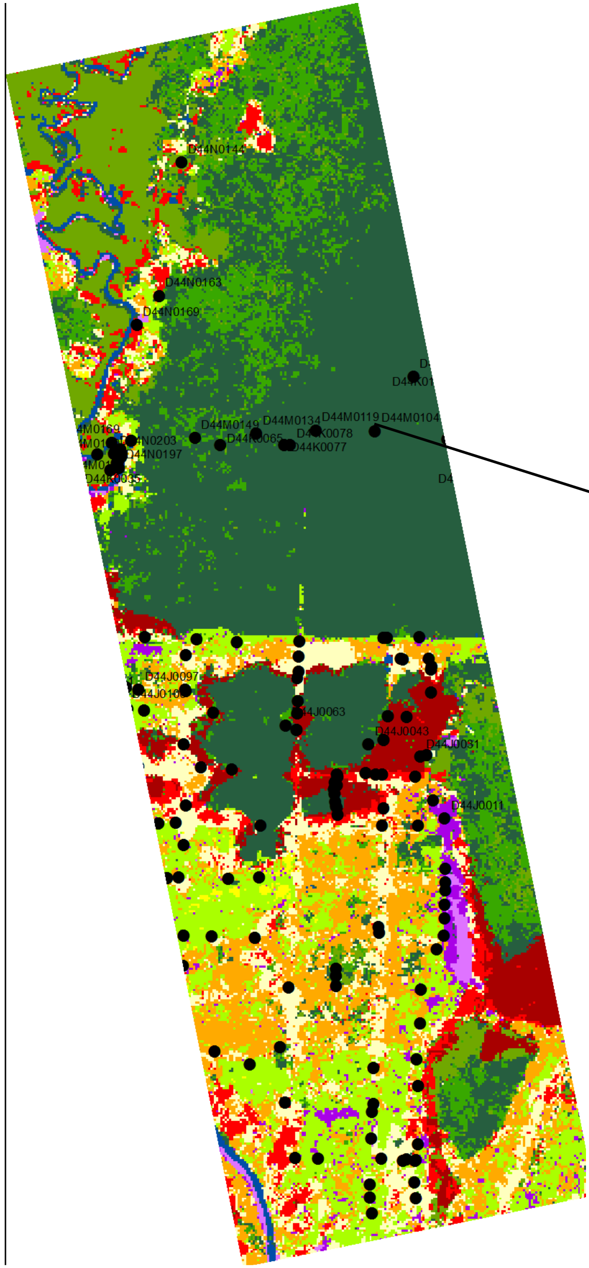

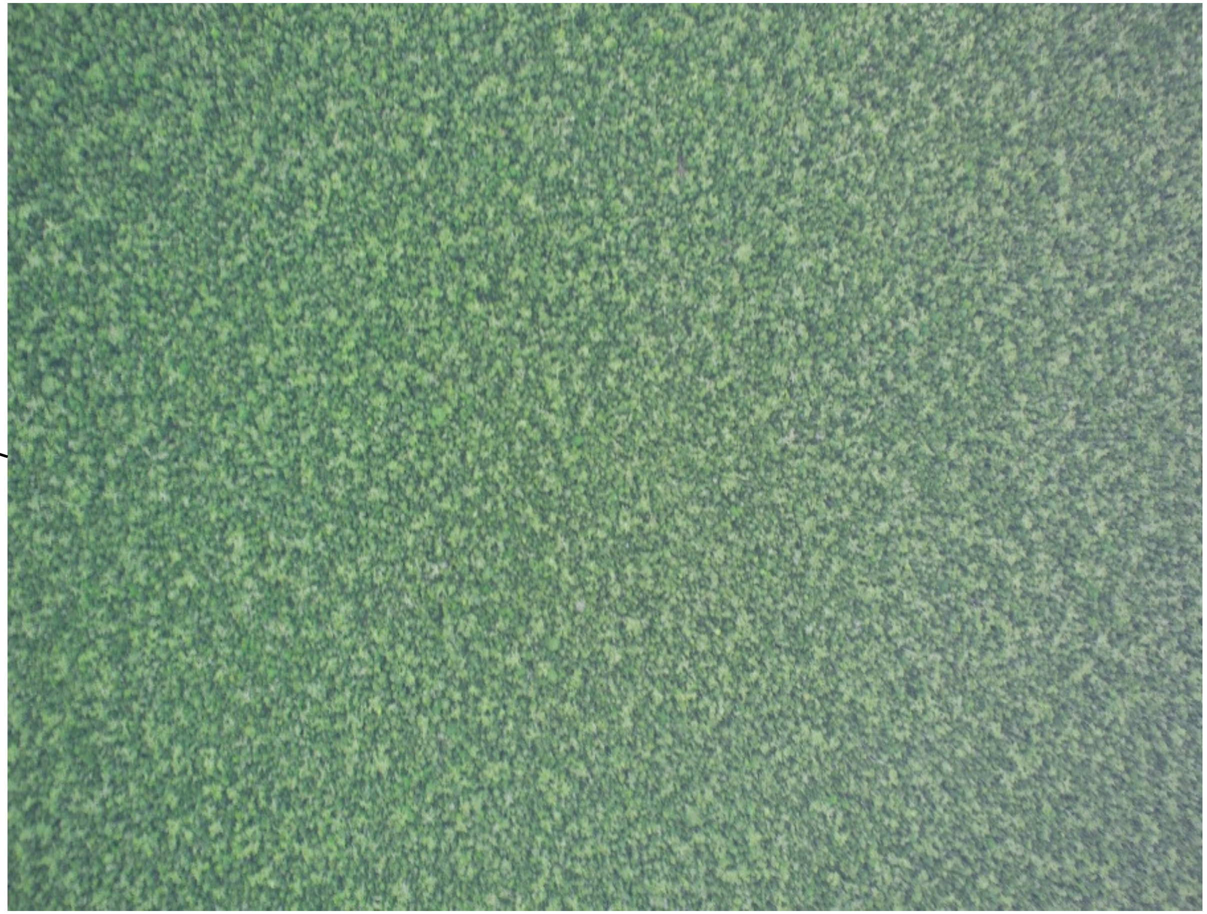

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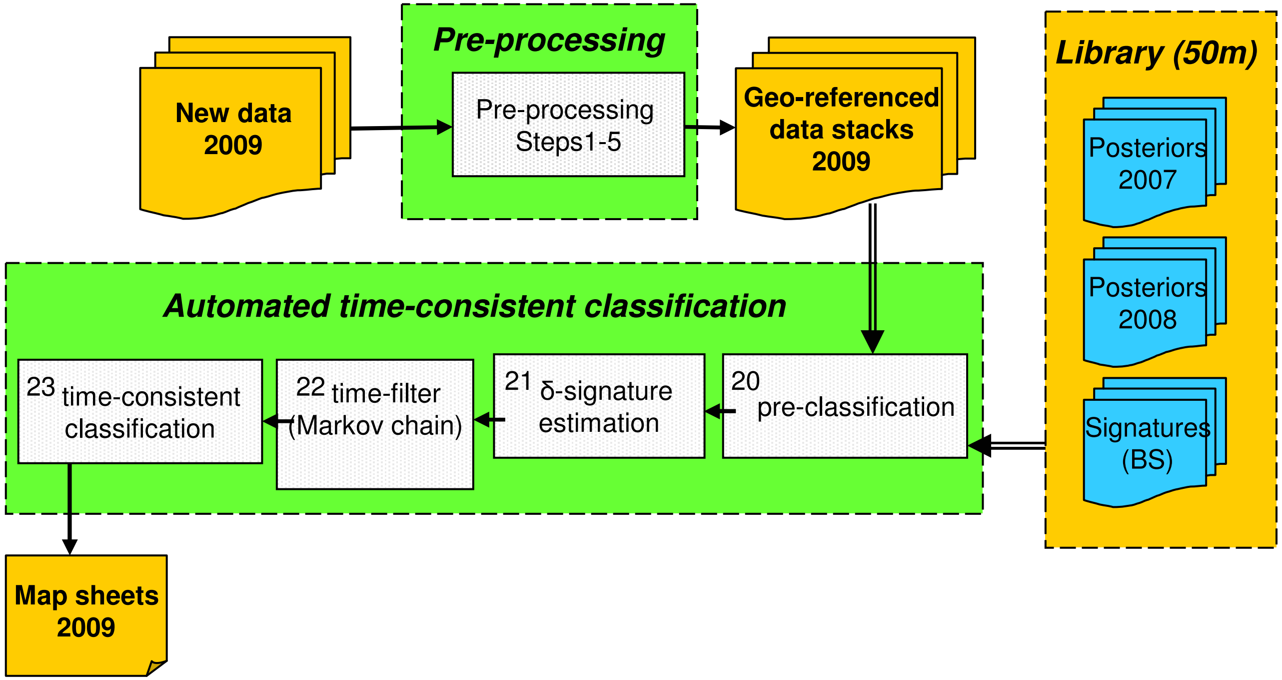
2. Change monitoring

Wageningen team: Borneo, Guyana

2. Consistent radar change monitoring



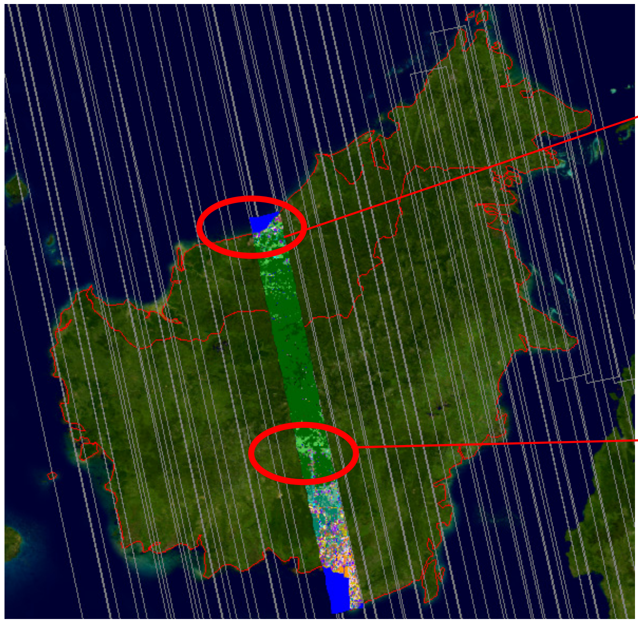
Operational processing chain is under development for systematic mapping of consistent time-series of change:

- **Forest - non-forest (Horizon-1)**
- **Land cover (LCCS) (Horizon 2)**

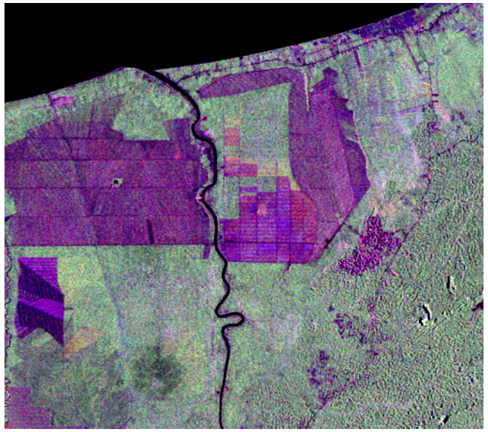
using ALOS PALSAR FBS and FBD strip data (50 m) *and* SLC (≤ 25m) data

Finding: moisture variations through time should be corrected for!

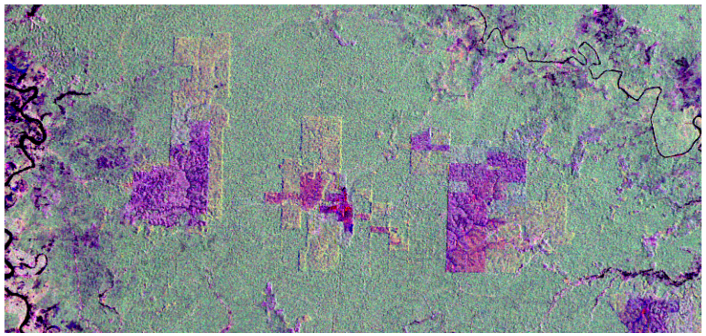
Even signatures of <u>stable</u> cover class can <u>change</u> through time



complete ALOS PALSAR track

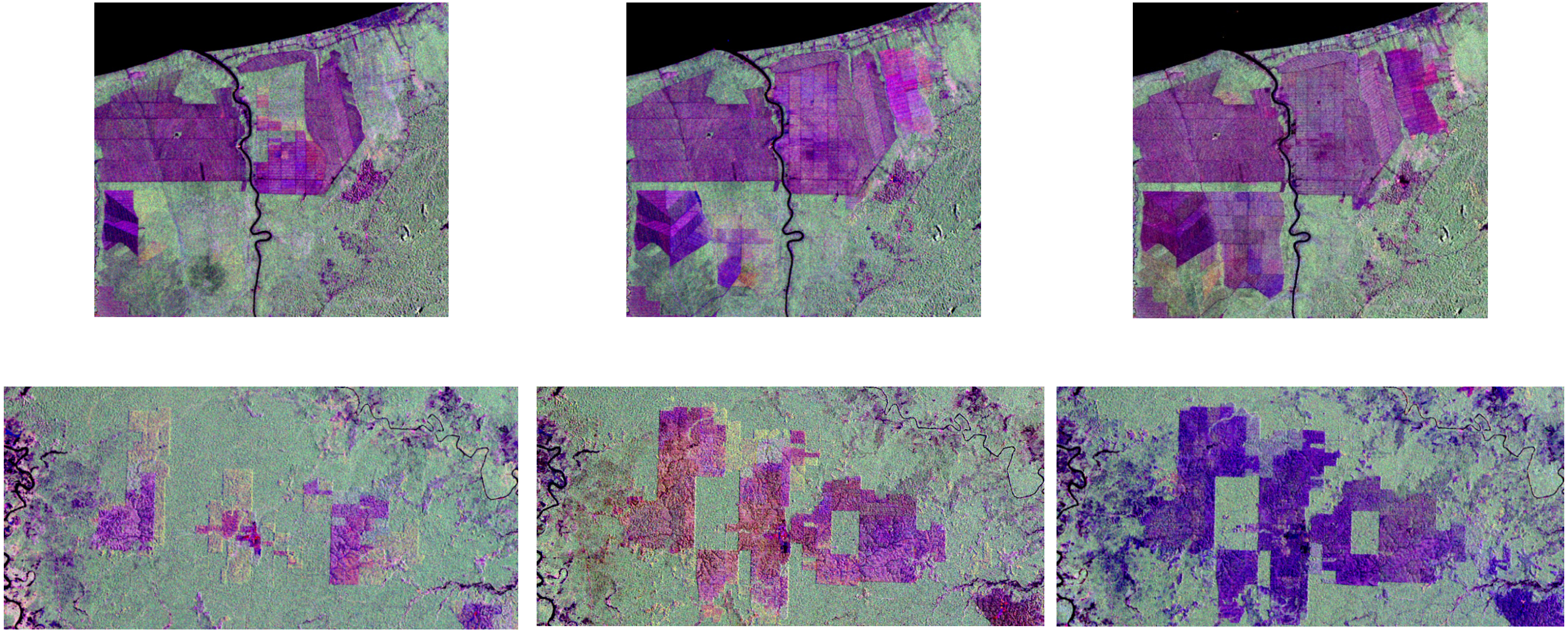


2007 Sarawak (North)



2007 Kalimantan (South)

2. Consistent radar change monitoring



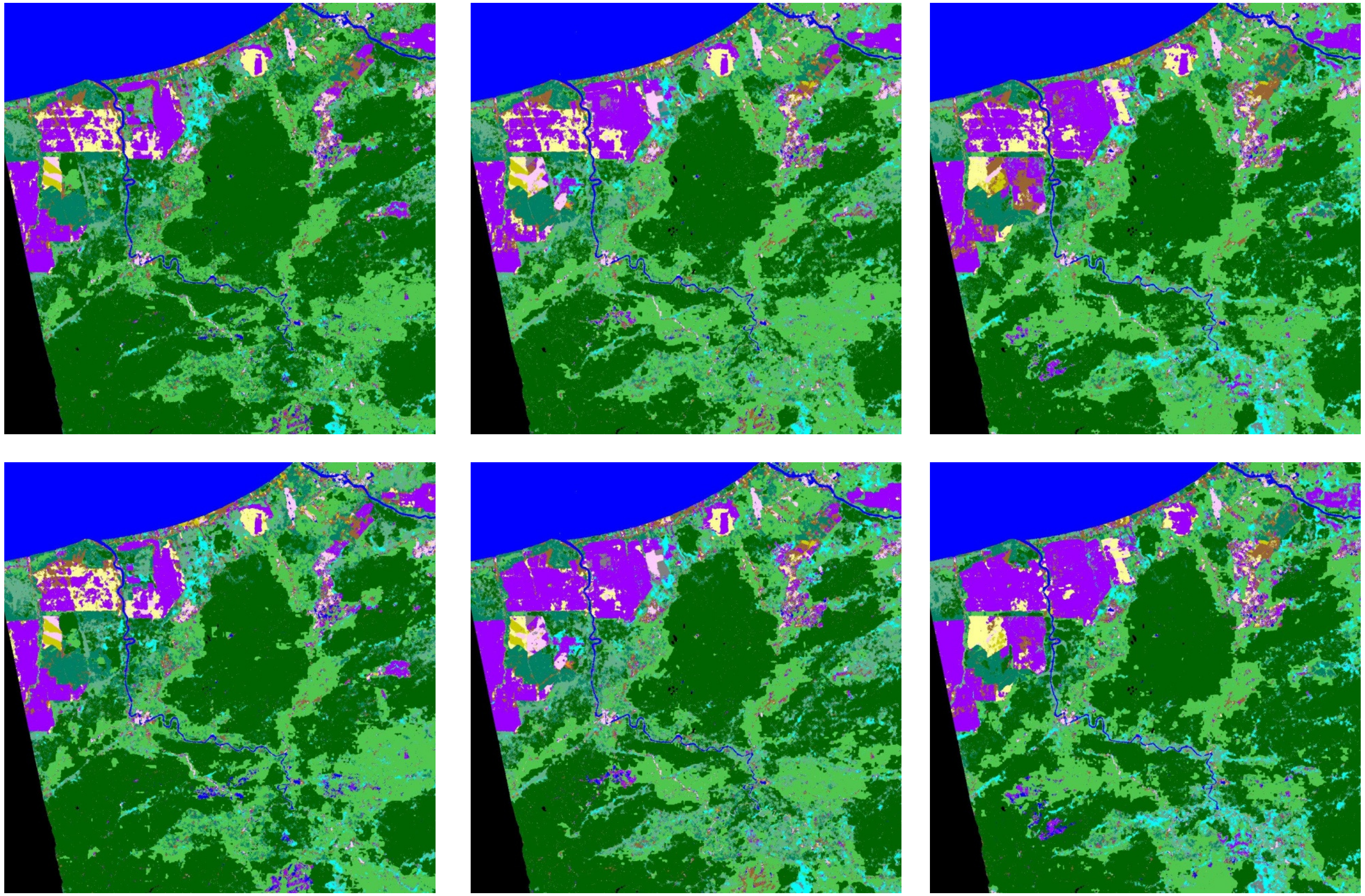
2007 2008 2009

2009: FBD-HH
-Drops in South
-Stable in North

2009: FBD-HV
-Drops in South
-Slight increases in North

2. Consistent radar change monitoring

Finding: time-series processing better than series of yearly maps



Consistent Time Series Classification

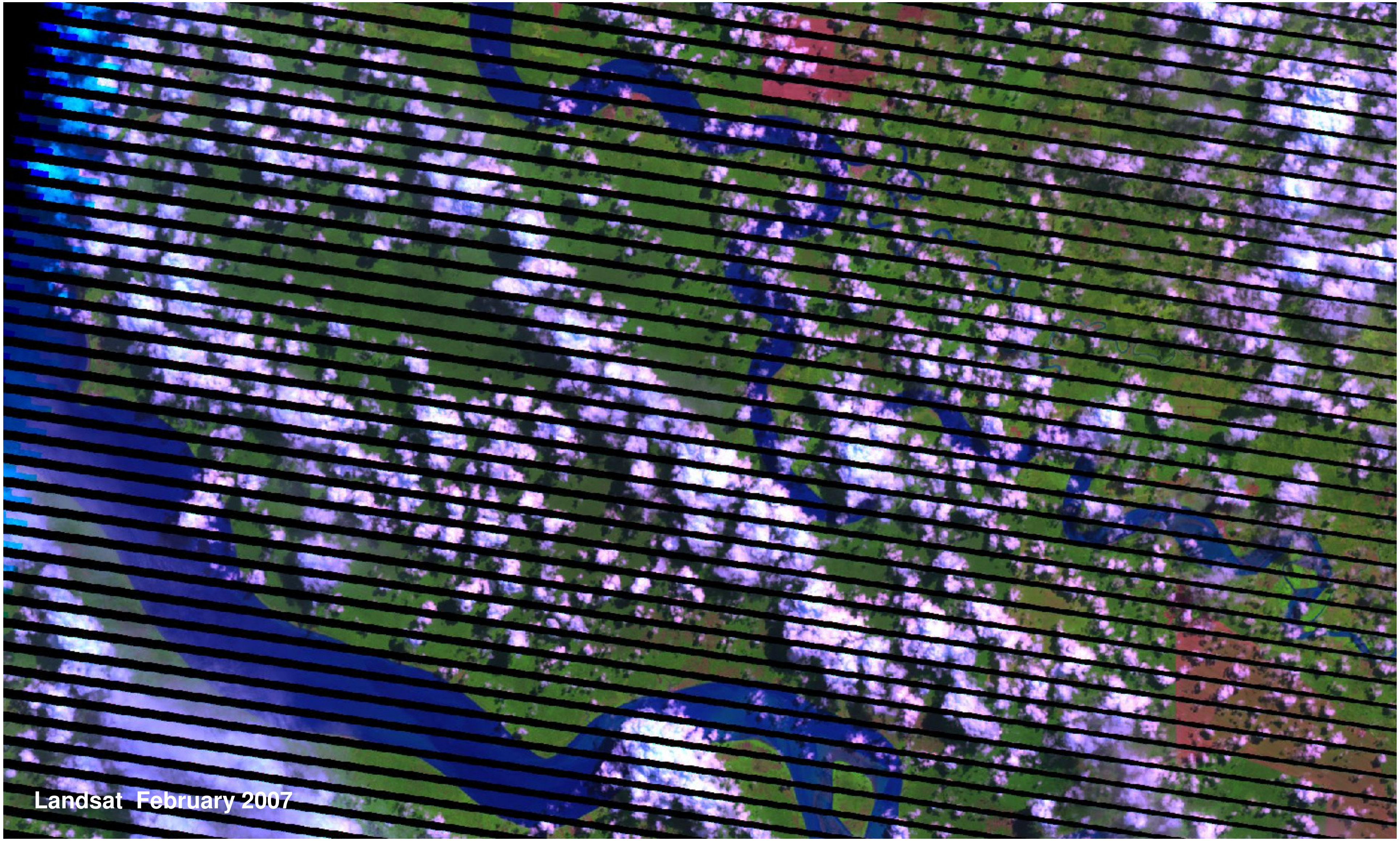
Single Year Classifications

2007 2008 2009

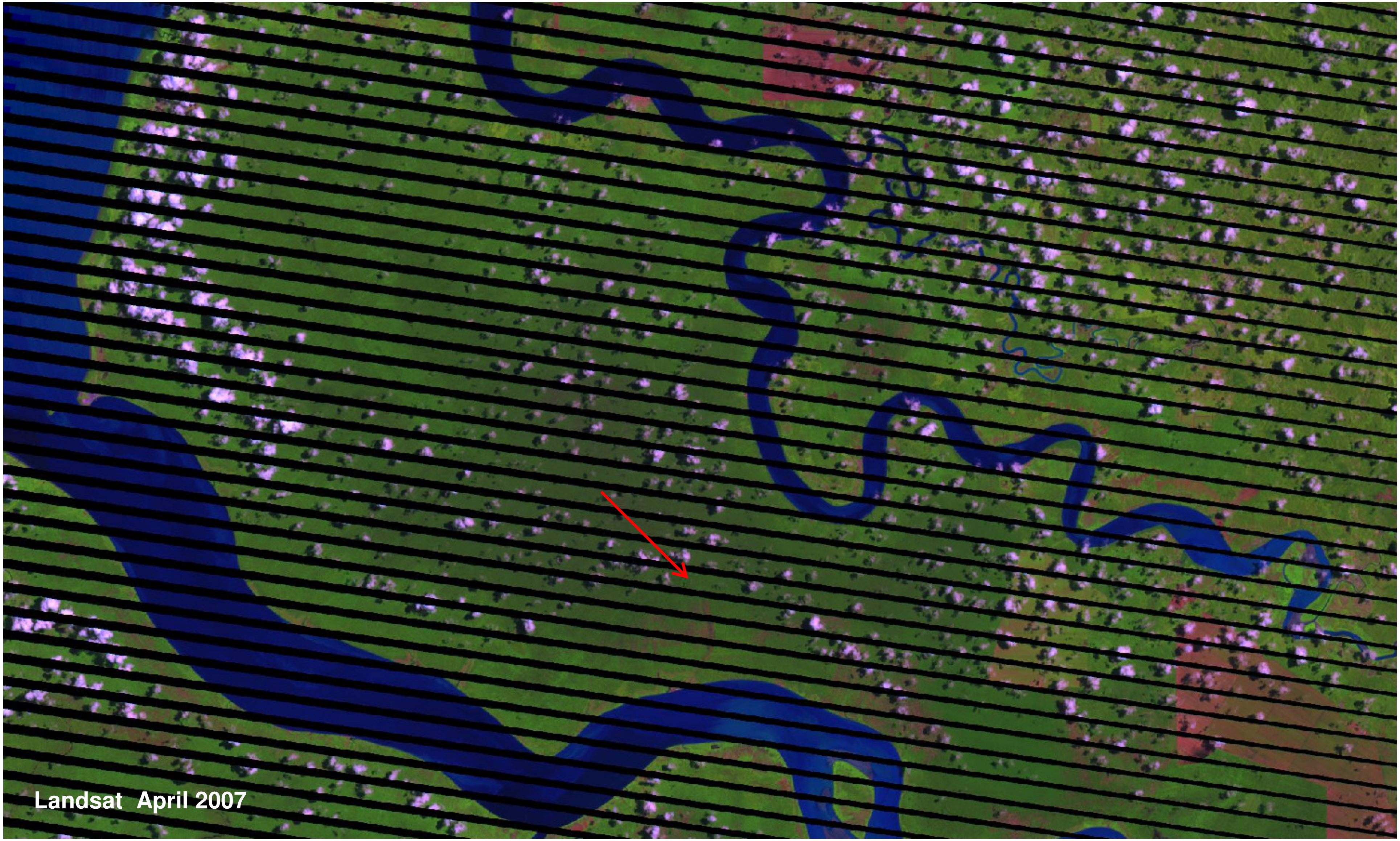
3. Progress degradation

ALOS PALSAR at 25m
TerraSAR-X at 1-6 m

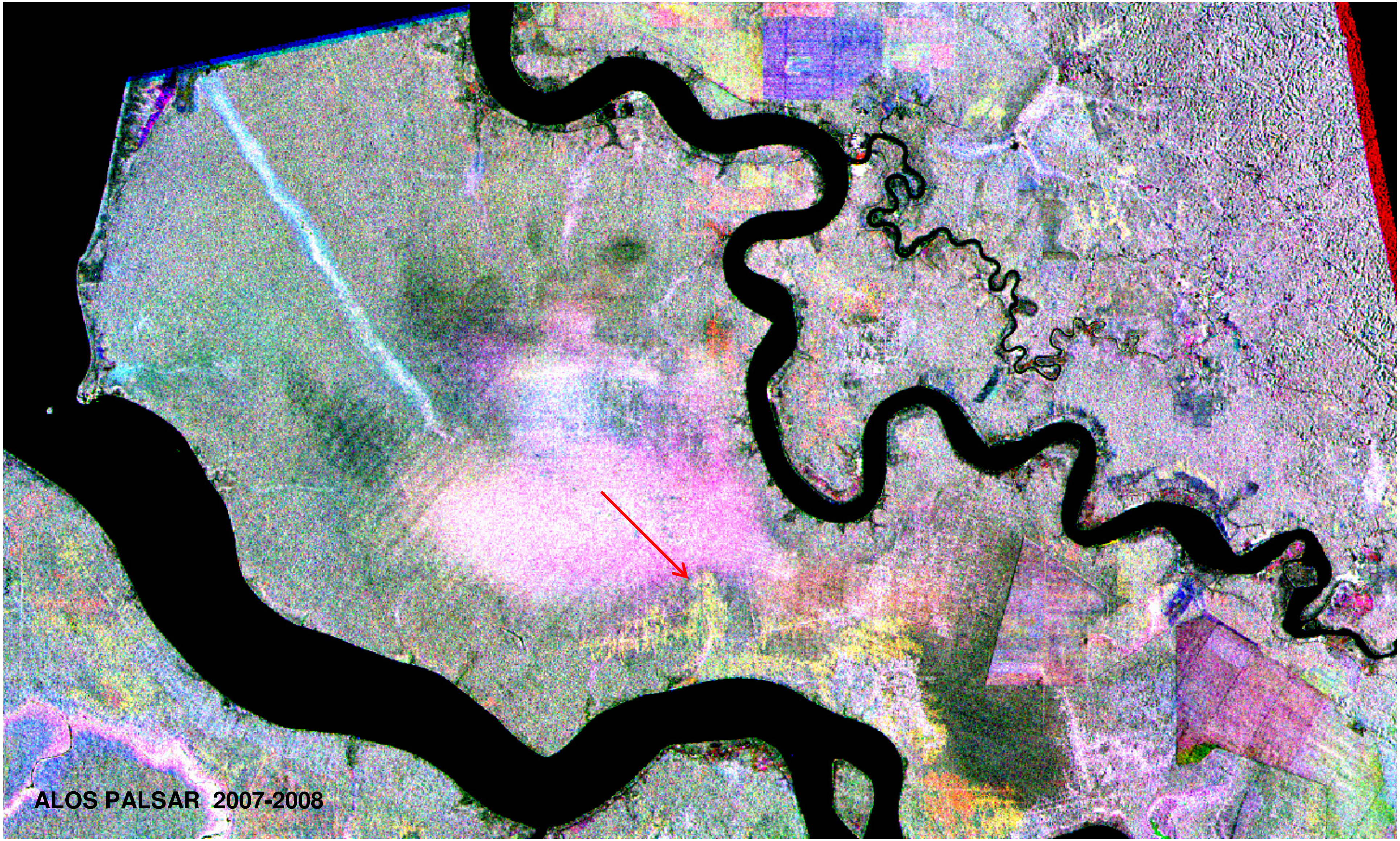
Example: Degradation ALOS PALSAR Borneo



Example: Degradation ALOS PALSAR Borneo



Example: Degradation ALOS PALSAR Borneo



Example: Degradation ALOS PALSAR Borneo

Example: Degradation ALOS PALSAR Borneo

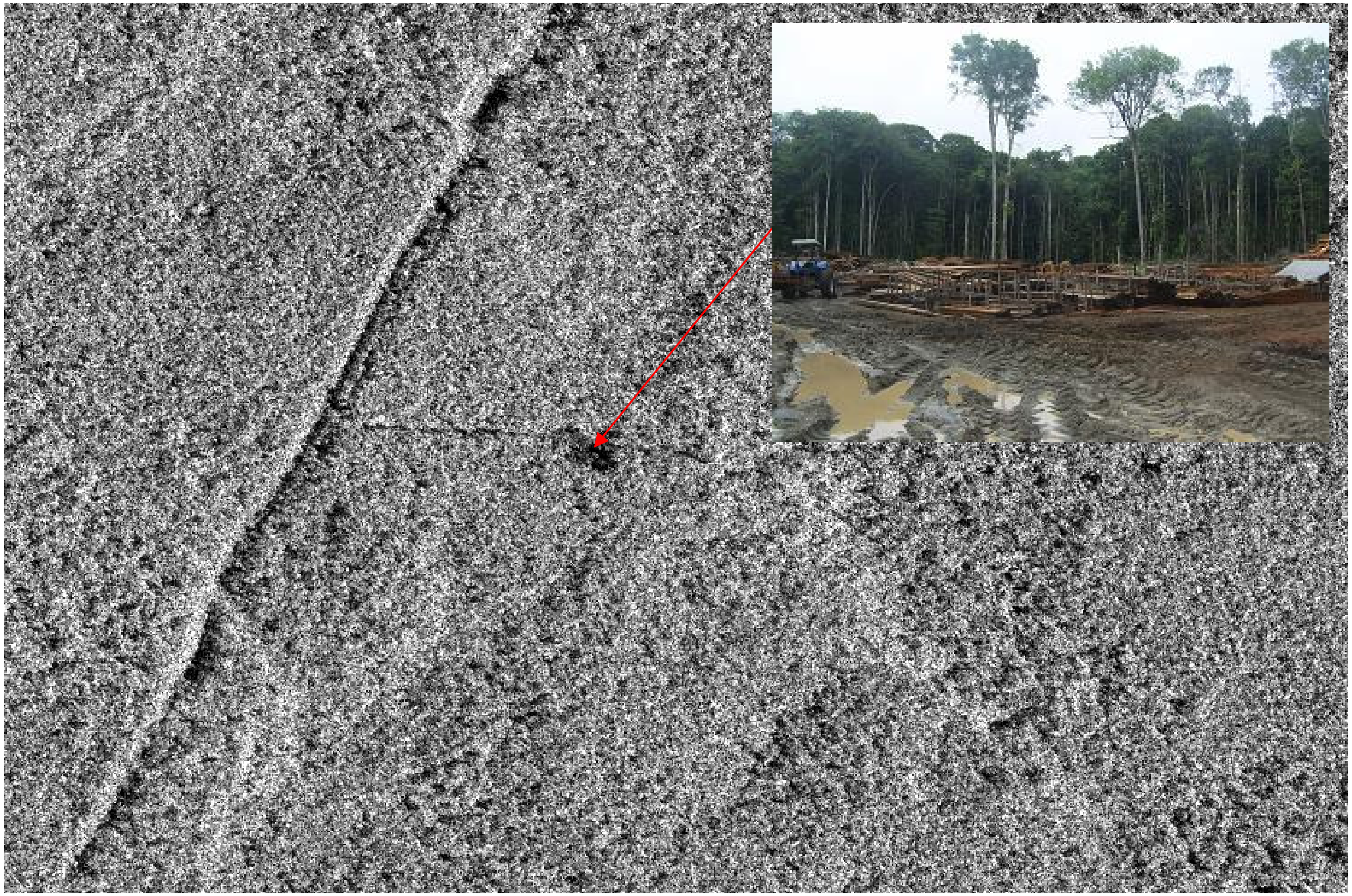
Example: Degradation TerraSAR-X Guyana

TerraSAR-X Spotlight mode – 1 m **1 information channel**

Example: Degradation TerraSAR-X Guyana

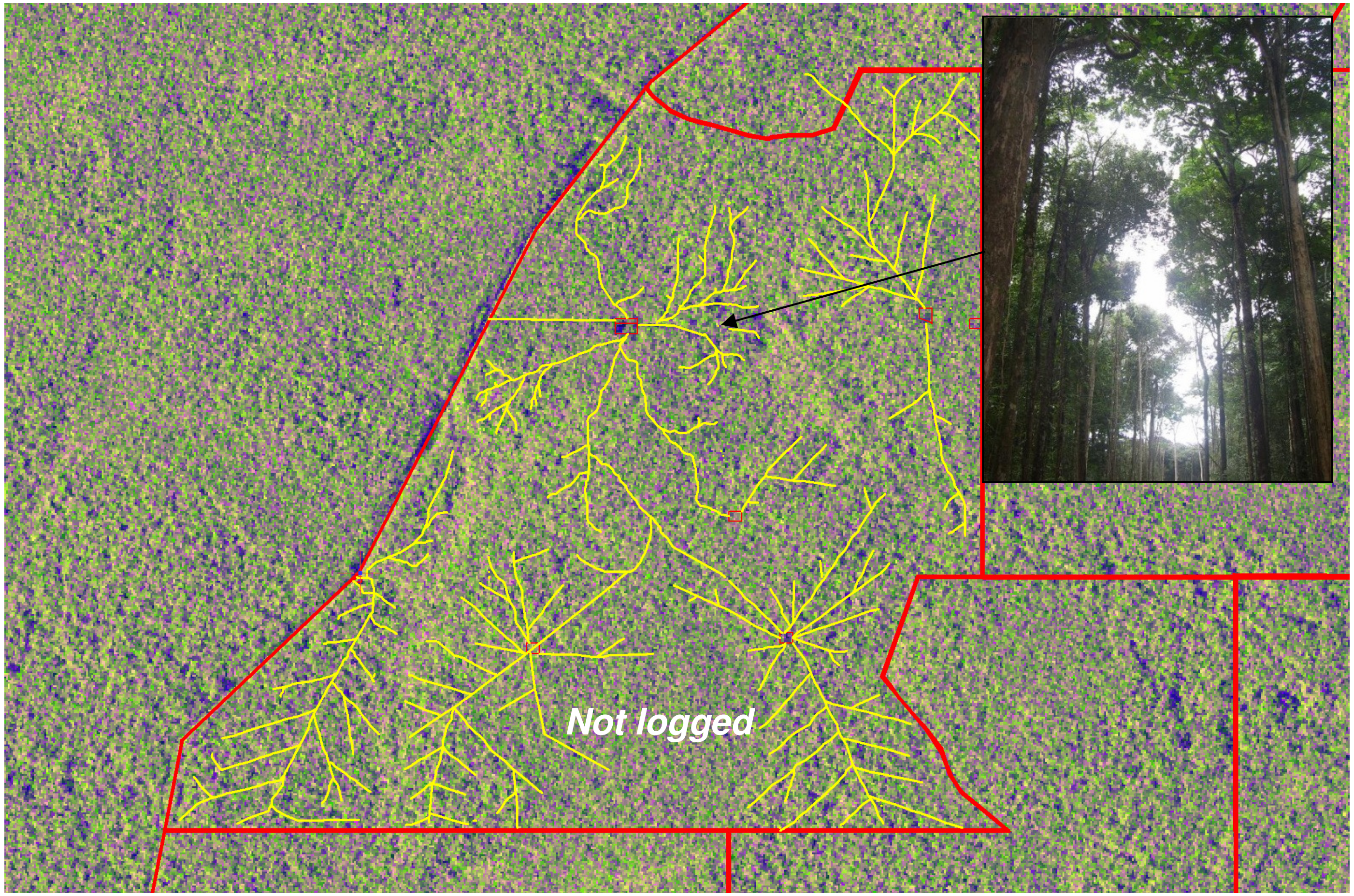
TerraSAR-X Spotlight mode – 1 m **1 information channel**

Example: Degradation TerraSAR-X Guyana



TerraSAR-X Spotlight mode – 1 m **1 information channel**

Example: Degradation TerraSAR-X Guyana



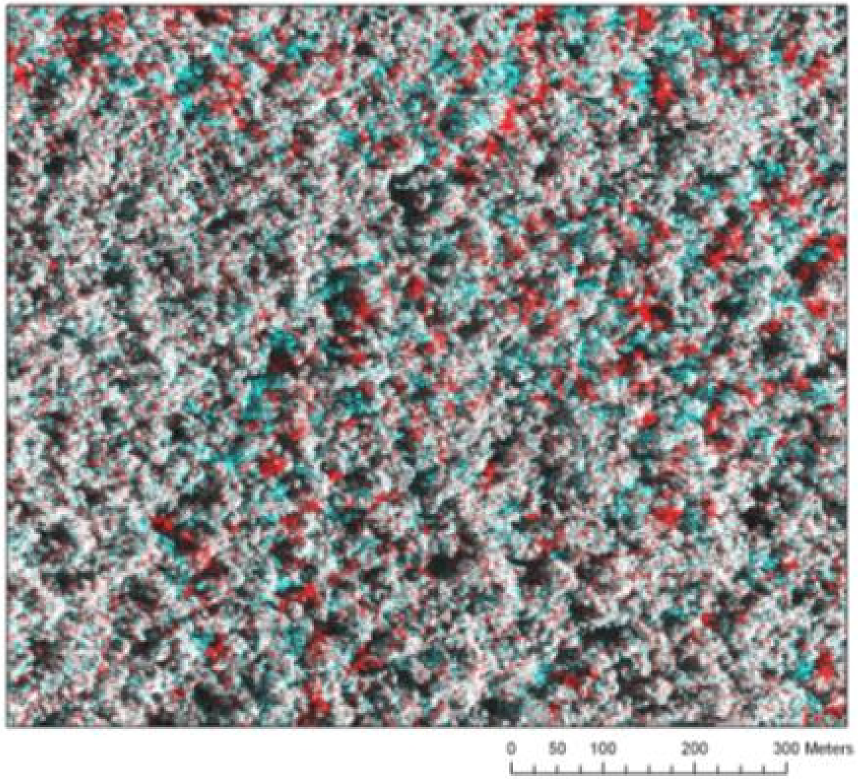
TerraSAR-X Stripmap mode – 6 m **2 information channels**

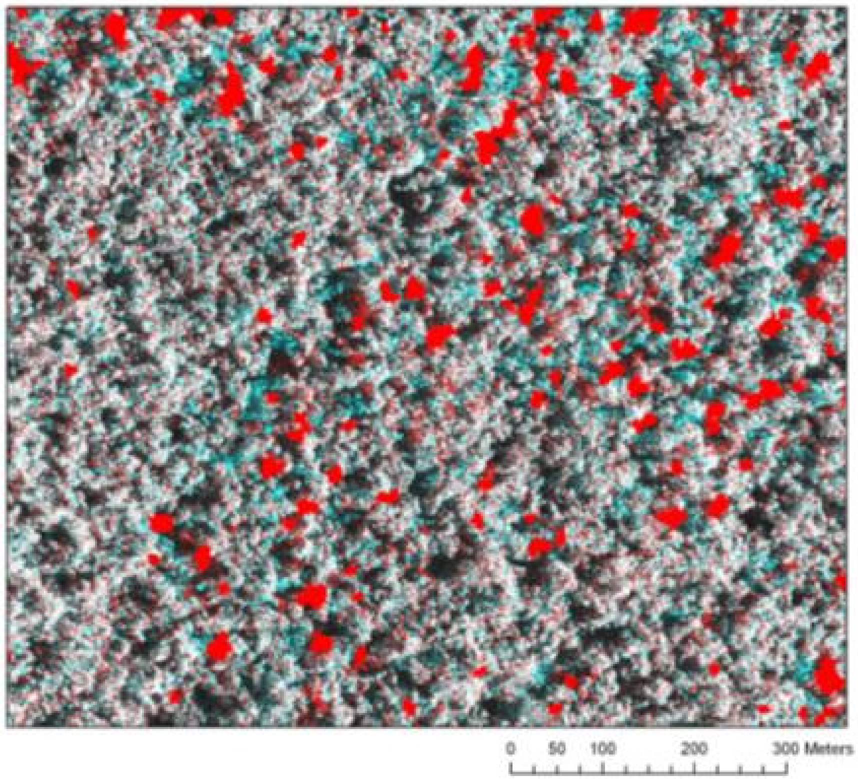
Used to map selective logging impact: tree felling canopy gaps, (some large) skid trails, and log markets

Example: Degradation TerraSAR-X Brazil

TerraSAR-X at 1m resolution: significant REDD+ potential

TerraSAR-X can provide information on changes at the individual tree level: systematic samplingscheme provides key input for Degradation monitoring





Left Spotlight images: R: 20080420; G: 20090817; B: 20090817. Right: logging gaps classification using simple thresholding.
Courtesy Kohl and Baldauf, Institute for World Forestry, and Infoterra.

To conclude

- Wide-area operational radar monitoring is feasible, yielding spatially consistent and timely wall-to-wall coverage of key vegetation types and changes required
- Radar time-series processing should be performed, with caution: consider moisture and use (automated) assessment of "differential radar signatures" to adjust radar signatures
- Potential for forest degradation with PALSAR and particularly TerraSAR-X individual tree monitoring on sampling basis
- Interoperability with optical sensors is strongly recommended. Achieving comparable results using different sensors will help to achieve the confidence required for operational monitoring

Thank you!

Acknowledgements

We are grateful for the support from CEOS, GEO-FCT, JAXA-METI/EORC, European Space Agency (ESA), USGS LPDAAC, NASA/University of Maryland, colleagues of the ALOS Kyoto and Carbon Initiative, Netherlands Ministry of Environment, Indonesian Ministry of Forestry, Provincial Government of Central Kalimantan, Central Kalimantan Peatlands Project (managed by Wetlands International and funded by the Dutch Ministry of Foreign Affairs (DGIS)), WWF Indonesia, BOS Foundation, Conservation International Guyana, UNDP-IUCN Guiana Shield Initiative.

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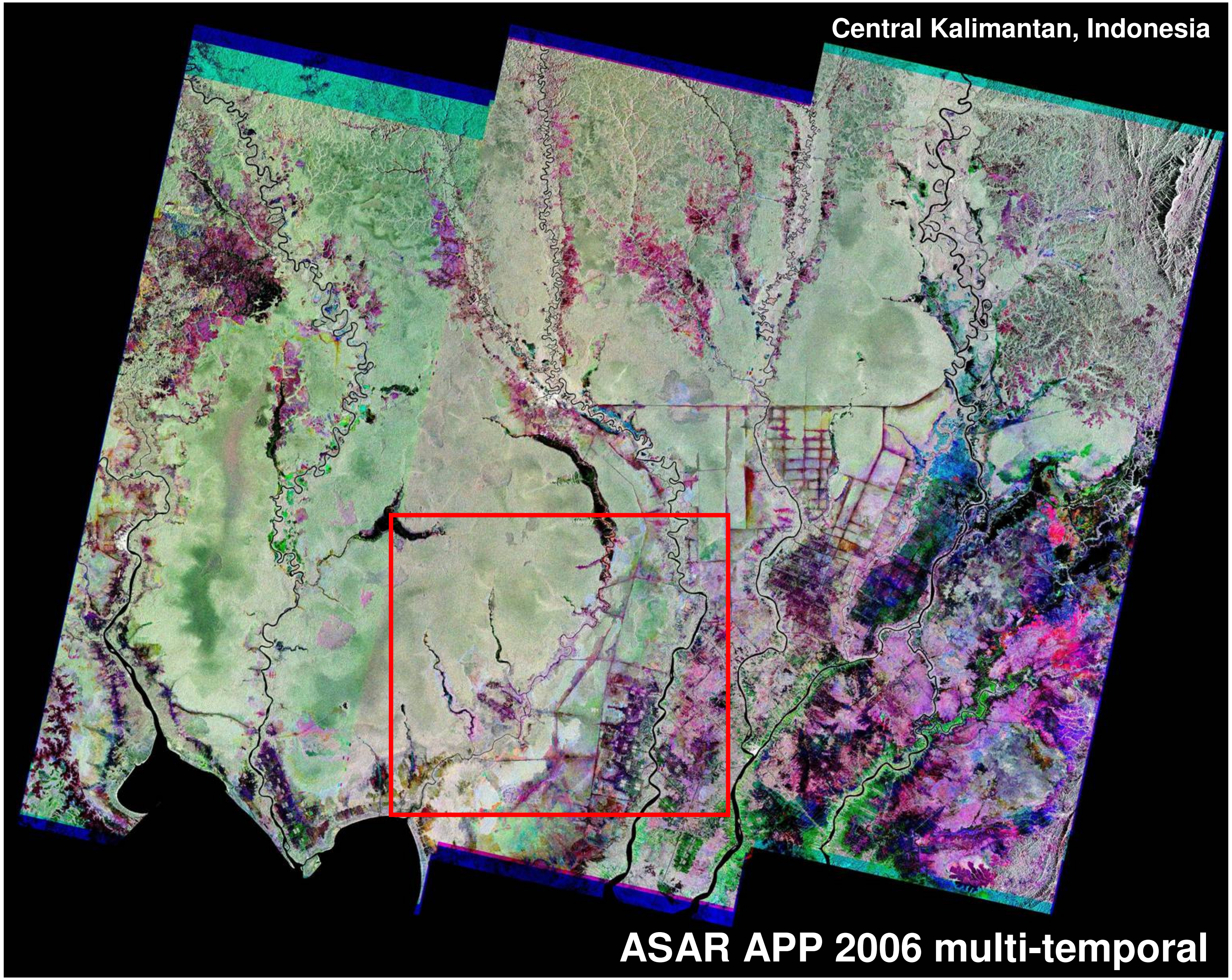
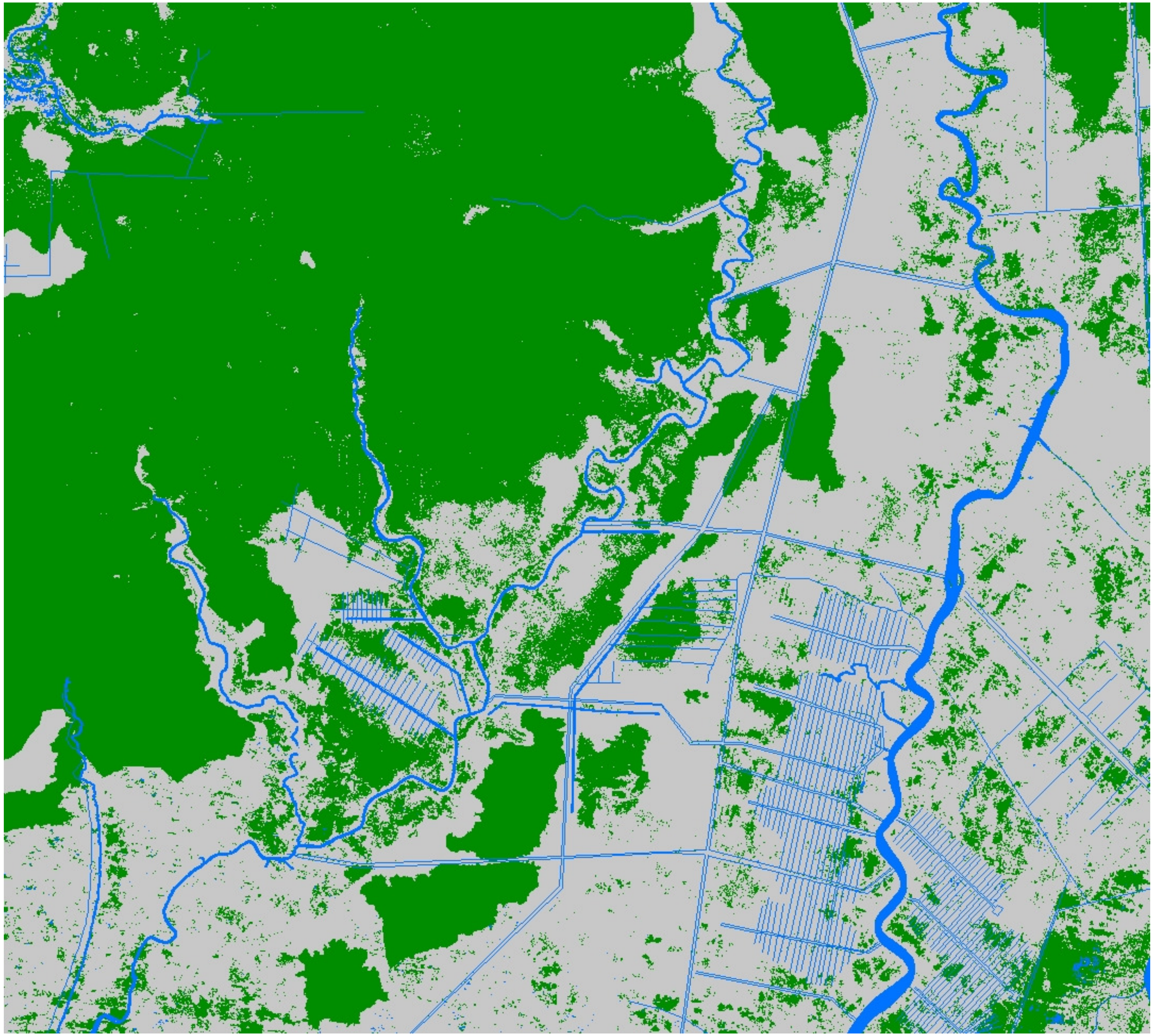
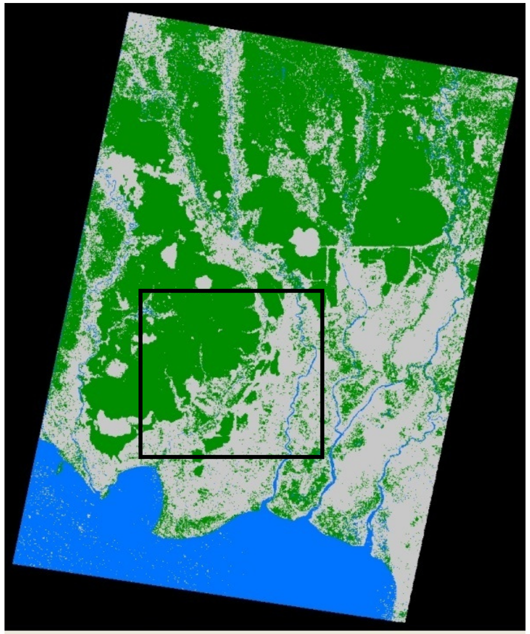
Examples: Envisat ASAR



Examples: Envisat ASAR

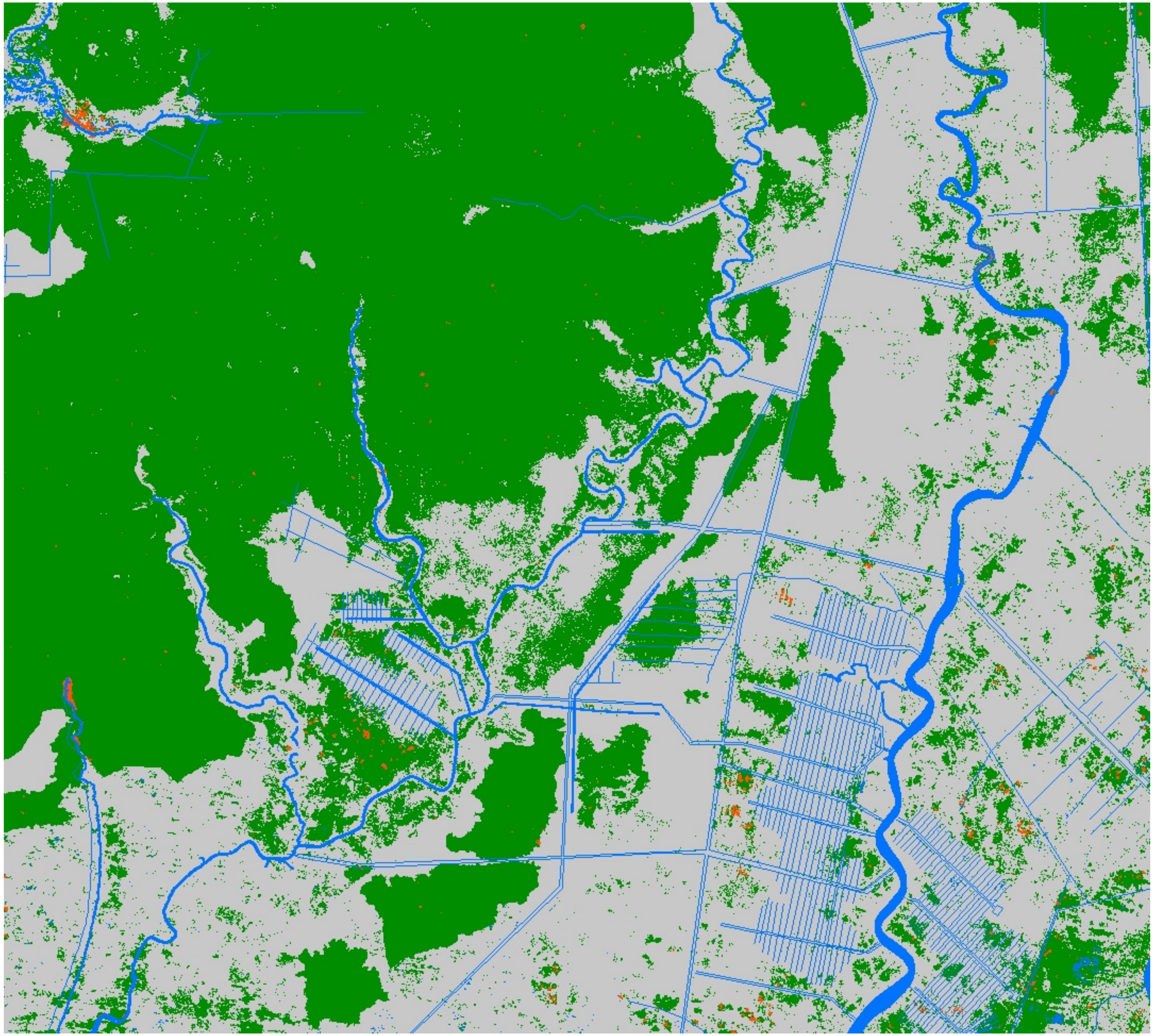


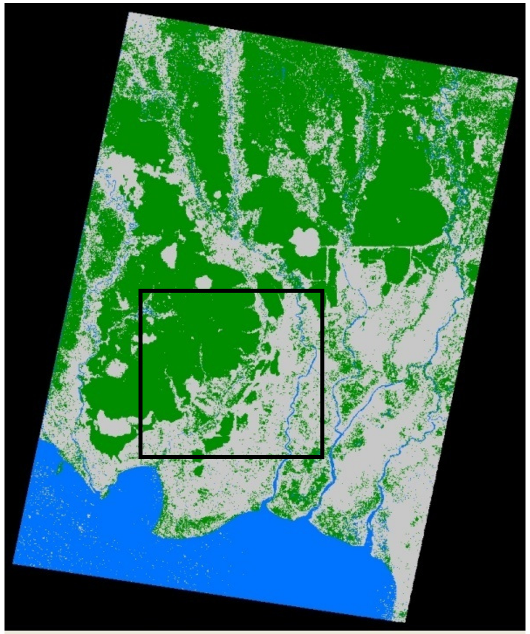


Forest mask

2005 base year

Examples: Envisat ASAR



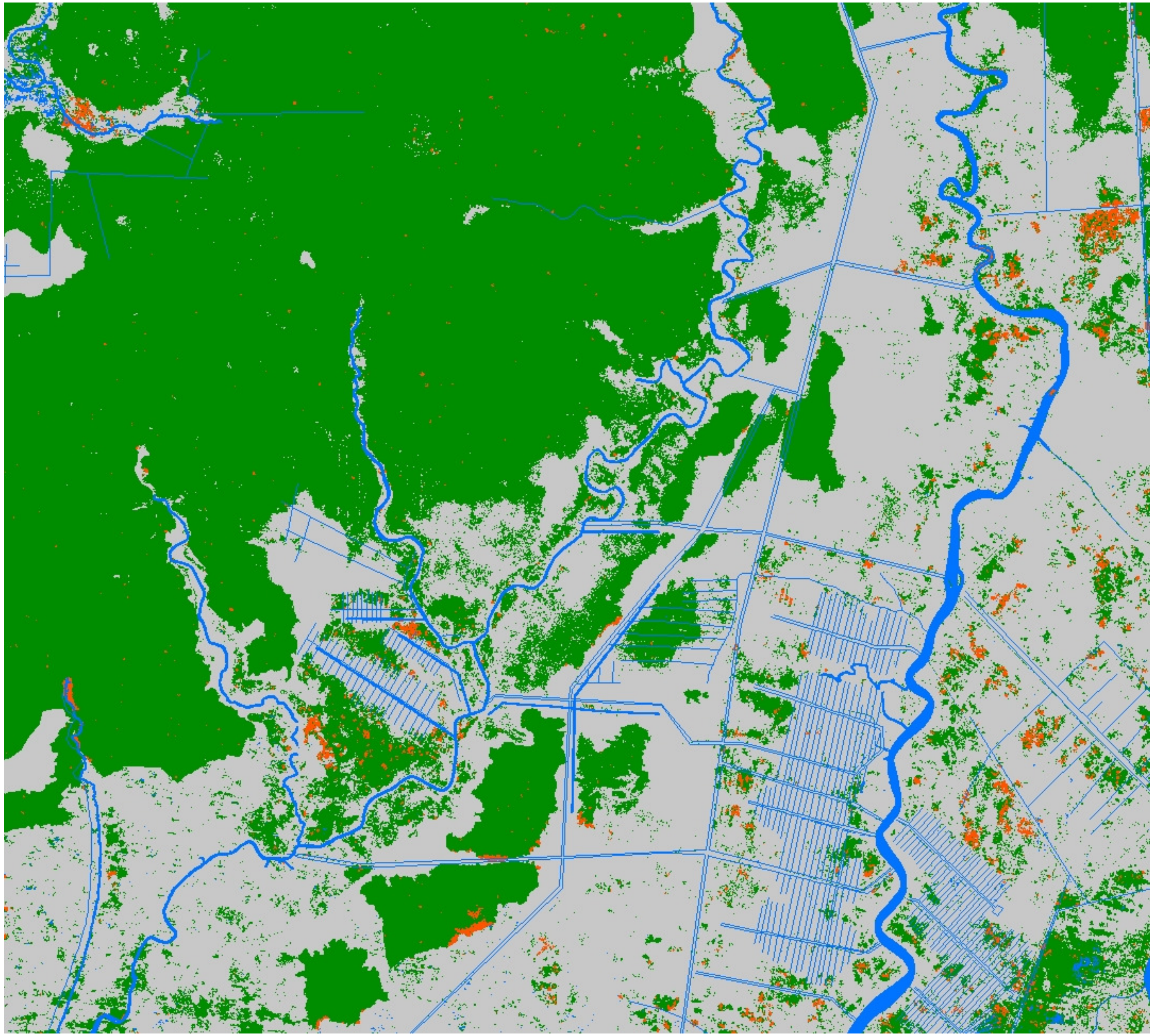


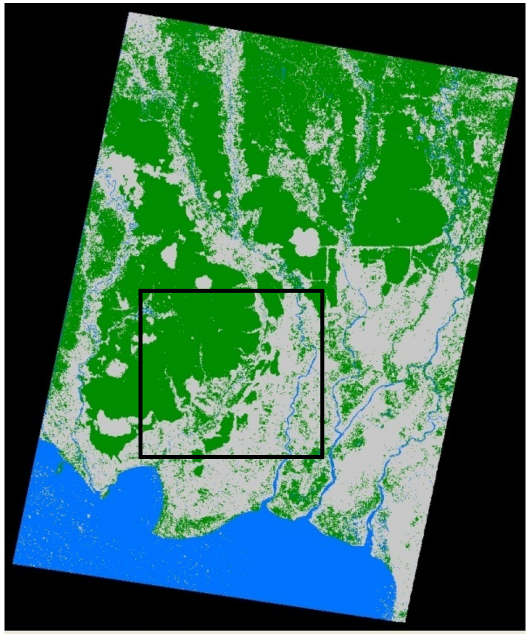
Orange – forest change

Radar changes

2006 Jan- Mar

Examples: Envisat ASAR



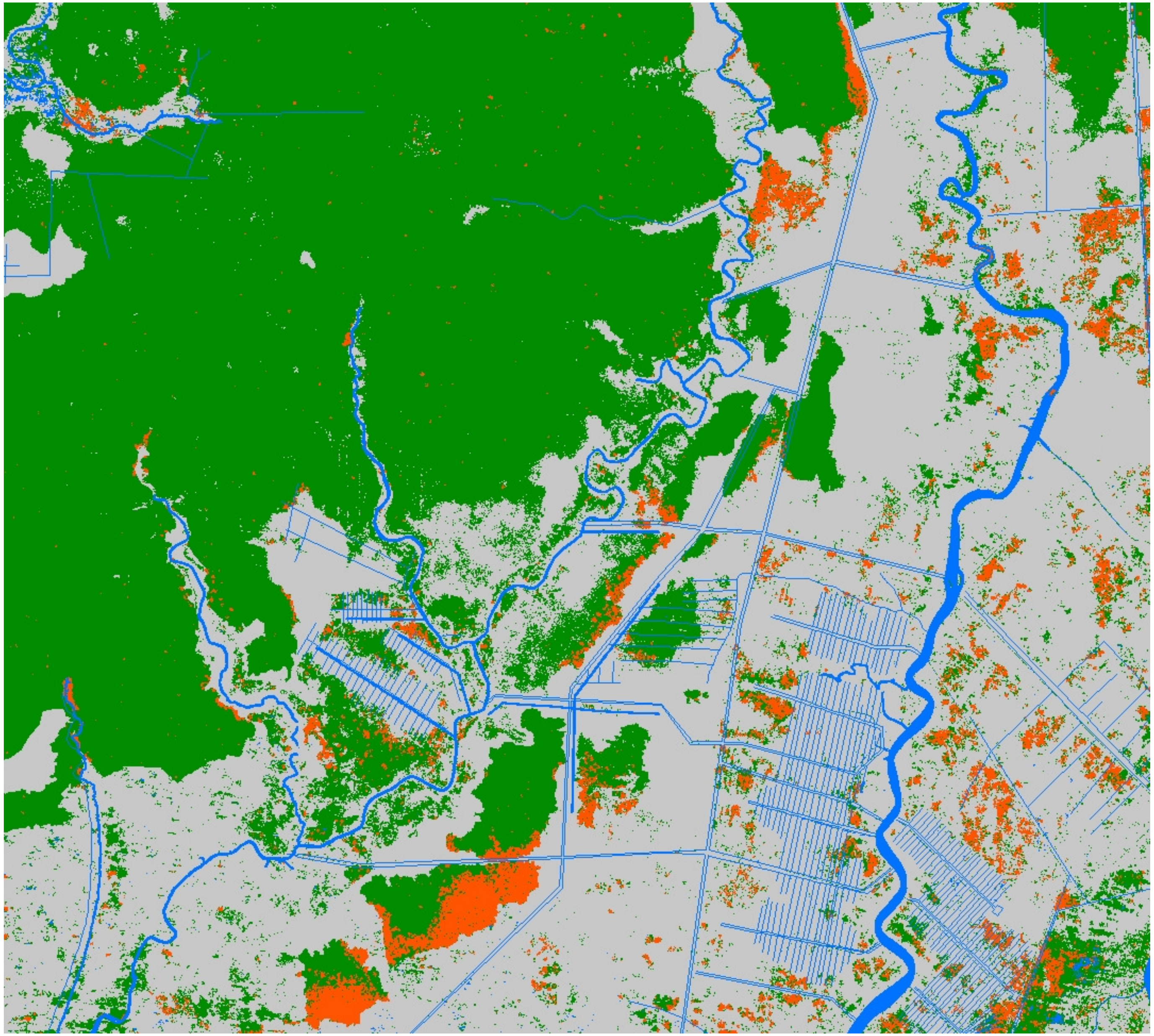


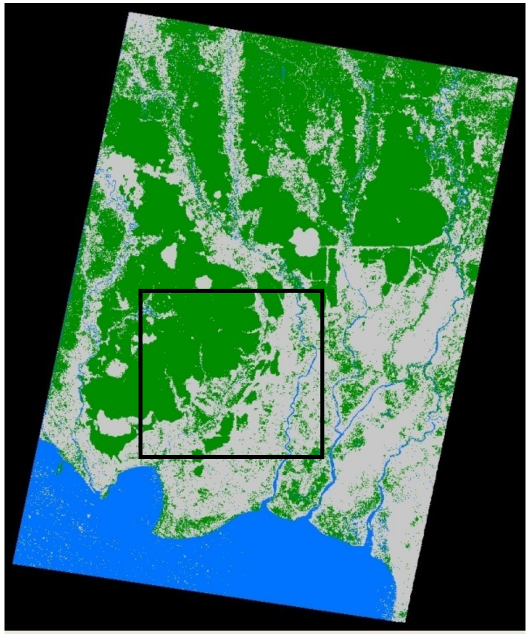
Orange – forest change

Radar changes

2006 Apr- Jun

Examples: Envisat ASAR



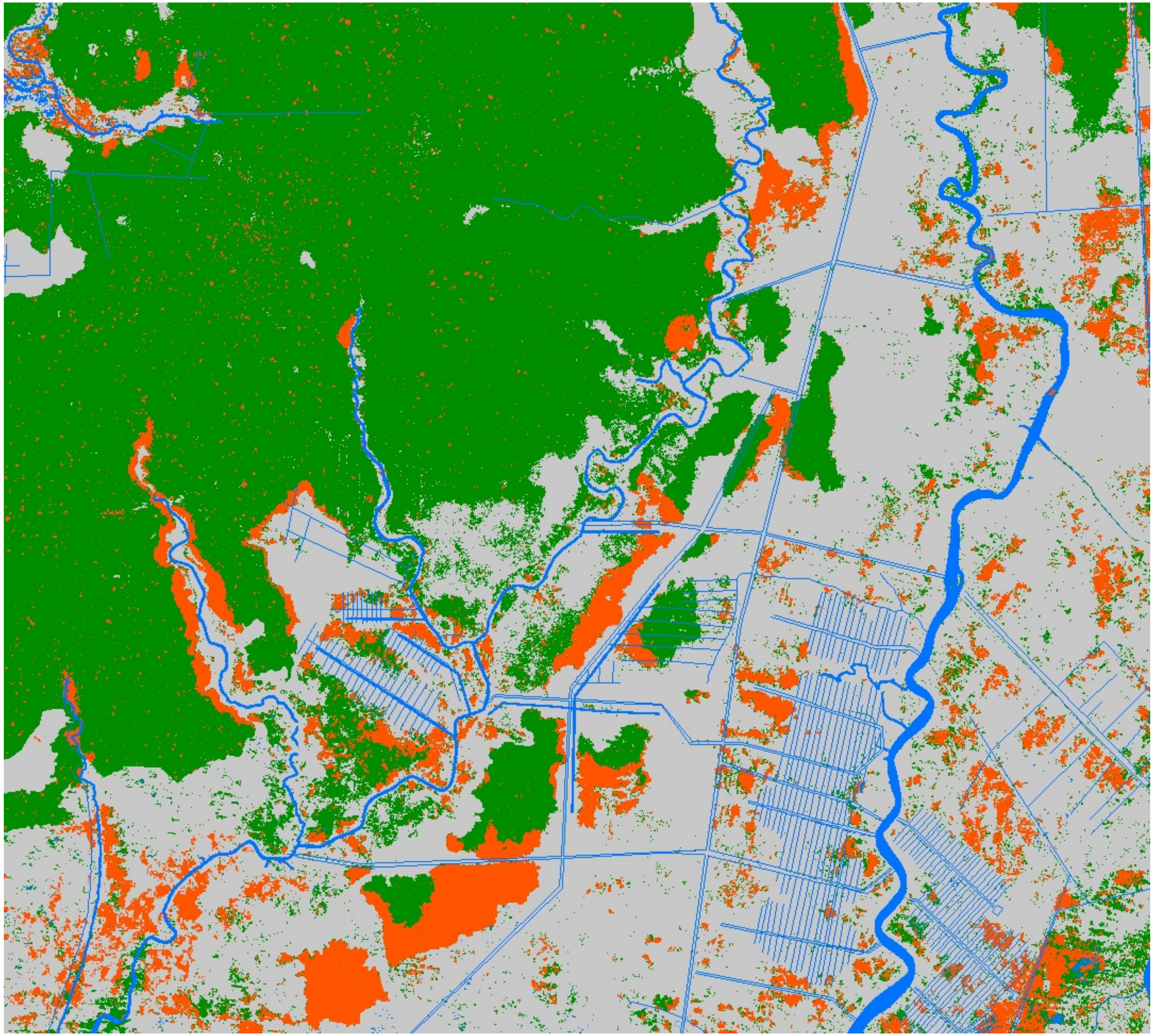


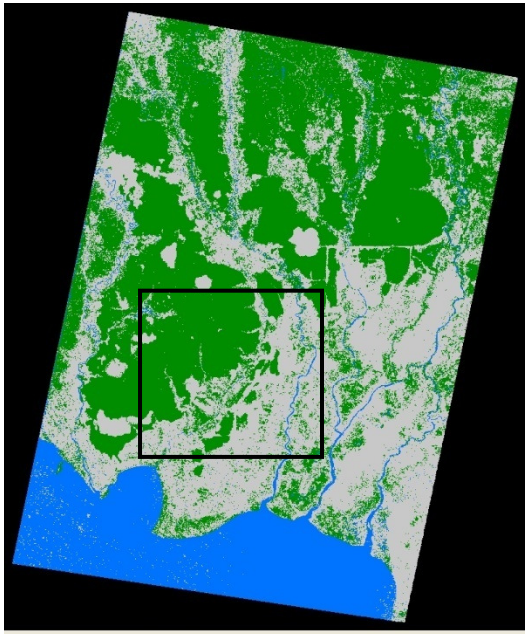
Orange – forest change

Radar changes

2006 Jul- Sep

Examples: Envisat ASAR



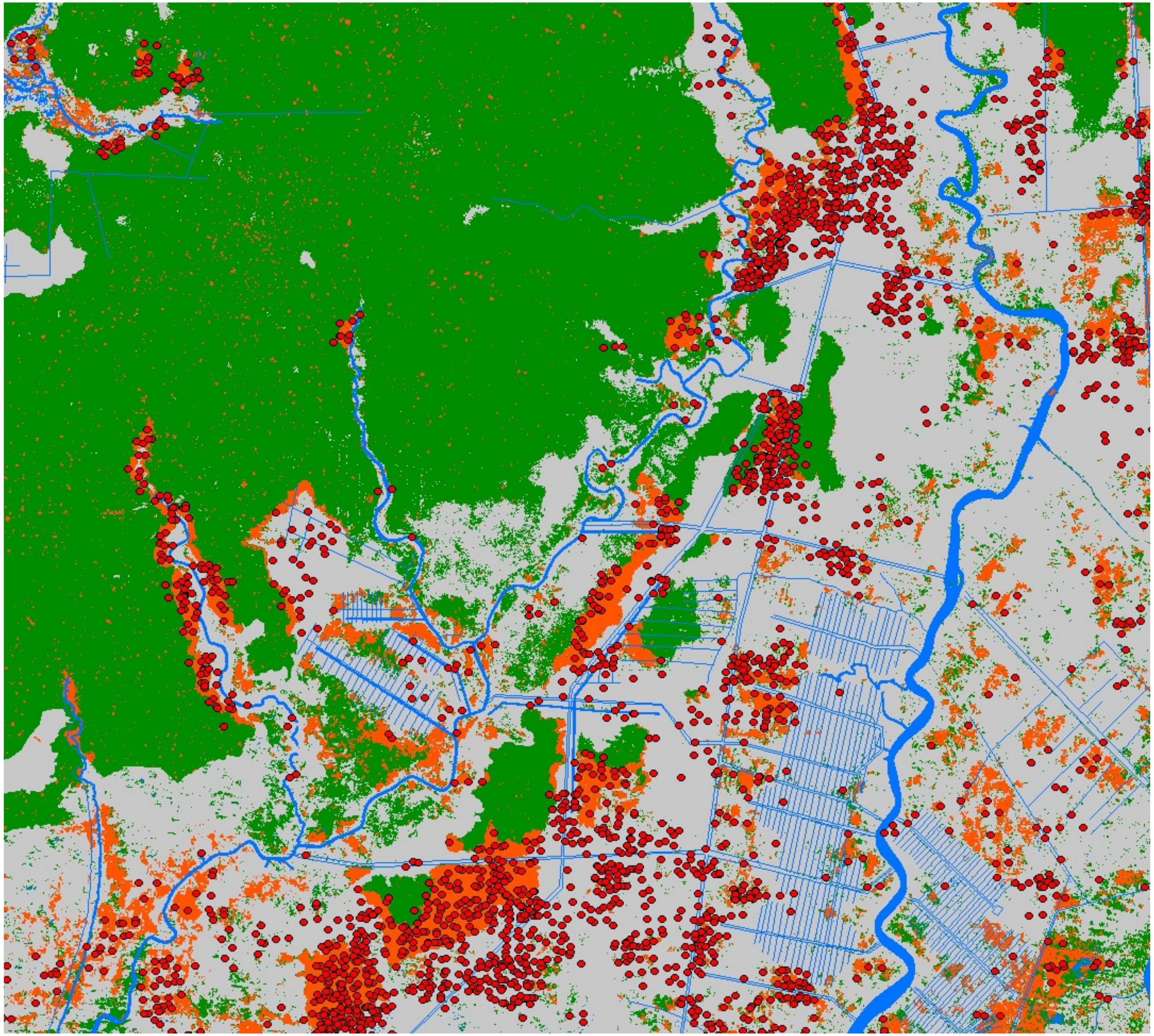


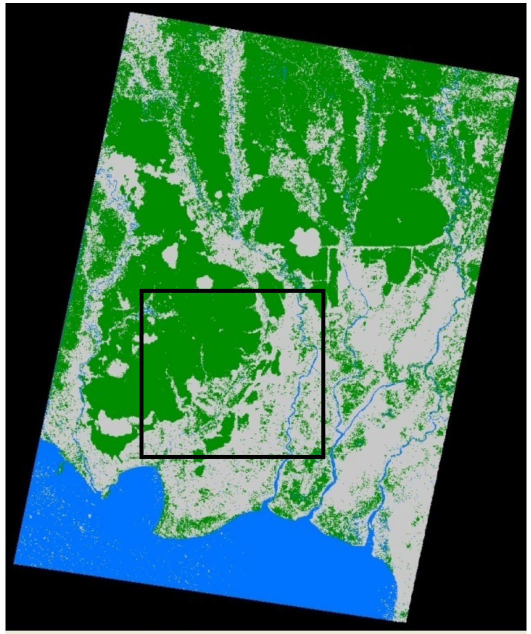
Orange – forest change

Radar changes

2006 Oct- Dec

Examples: Envisat ASAR



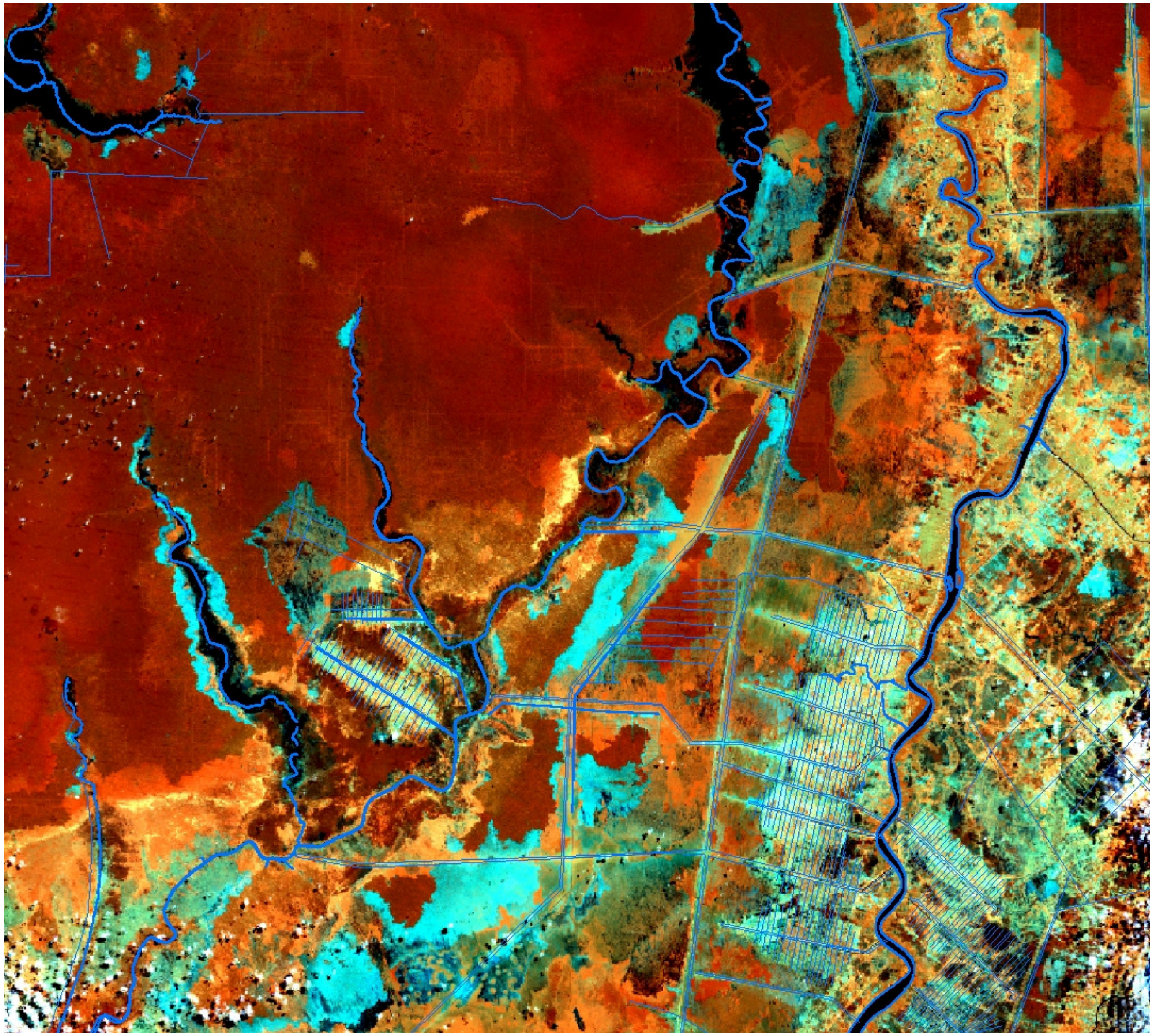


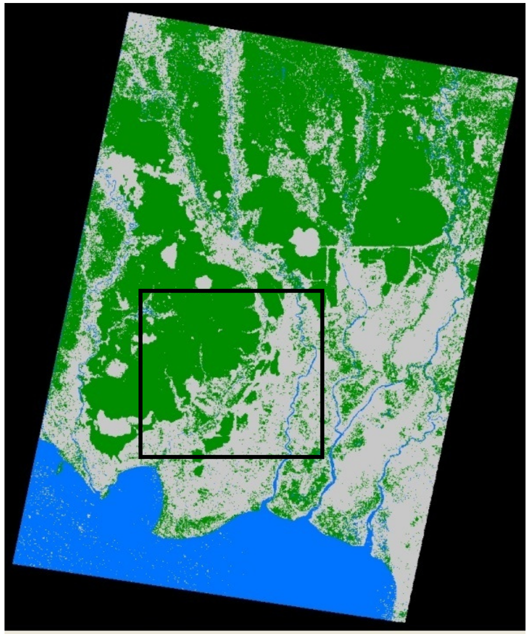
Orange – forest change

● – fire detection

2006 fire detections

Examples: Envisat ASAR





Landsat 457

2007 control