K&C Phase 4 – Status report

F7: Wide area forest monitoring of
Insular SE Asia and Guiana Shield

Dirk Hoekman
Wageningen University

Martin Vissers, Boris Kooij and Marcela Quiñones, SarVision

Science Team meeting #22
Tokyo, Japan, February 16-18, 2016

Project outline and objectives

1. Continue development of techniques for time-consistency (PALSAR-1/2) and the use of ScanSAR in dynamic and irregularly inundated areas. Integration with C-band Sentinel-1 data, which may significantly increase possibilities for land cover and biomass stratification.
2. Wide-area application of the multi-model slope correction model (entire Borneo).

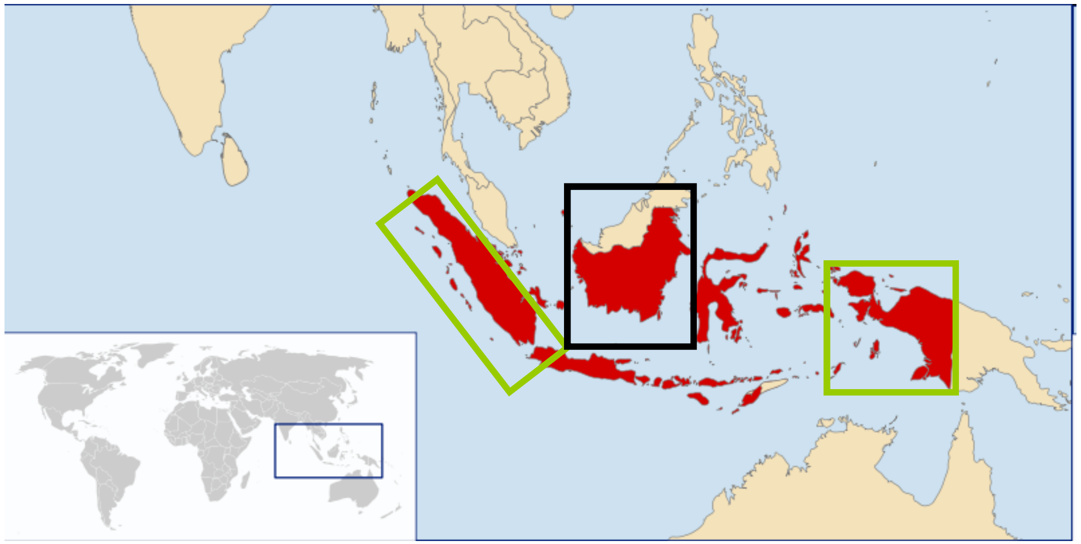
Project outline and objectives

3. Integration of PALSAR data, aerial LiDAR/photography and field data to support the development of carbon accounting methodology for the Indonesian REDD agency (in collaboration with Bill Salas; 60 LiDAR sites in Kalimantan).
4. Forest baseline mapping and decadal change mapping (using PALSAR-1/2 and JERS-1).
5. Study of forest degradation (in combination with TerraSAR-X data at sites in Brazil and Sumatra).

Project outline and objectives: *project areas*

Focus on two major biomes with persistent cloud cover:

- **Guiana Shield**, with focus on Guyana, Suriname and Brazilian state of Para
- **Insular SE Asia**, with focus on Borneo, Sumatra and Papua (Indonesian part of New Guinea)



Project outline and objectives: *thematic drivers*

Carbon cycle: Contribution to operational national MRV systems, such as INCAS and Indonesian REDD agency

Climate change: Contributions to GFOI and UNFCCC

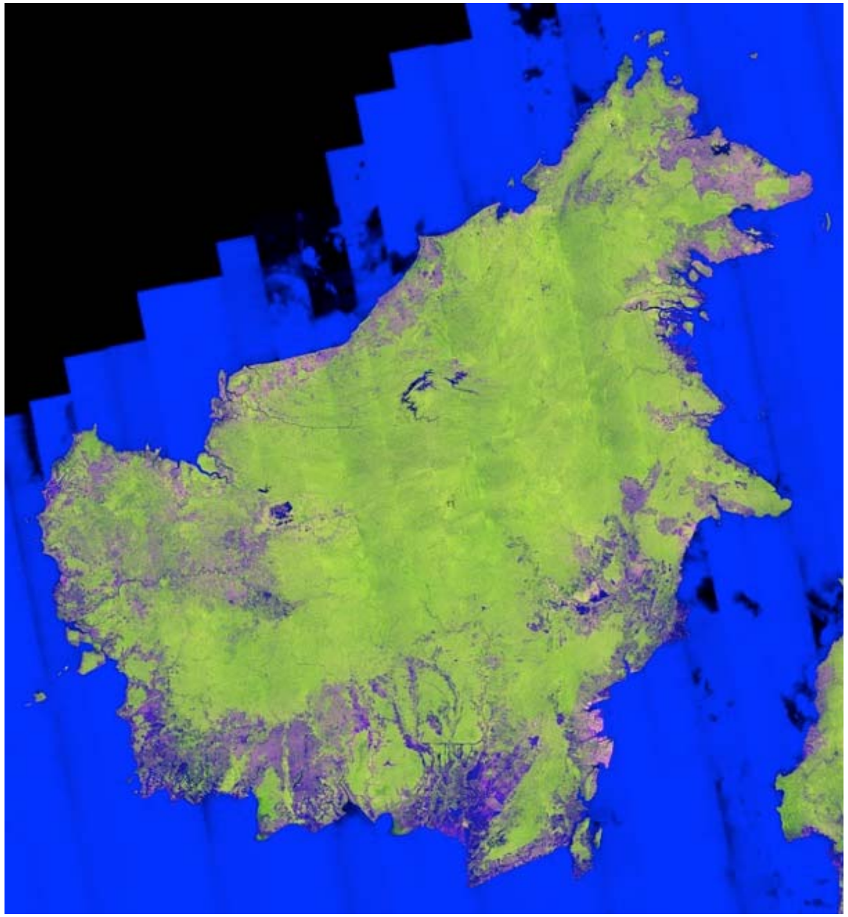
International **C**onventions: Monitoring Ramsar sites, such as Danau Sentarum National Park, Indonesia

Environmental **C**onservation: Early alert and degradation monitoring (using PALSAR, Sentinel-1 and TSX); Indigenous reserves Para.

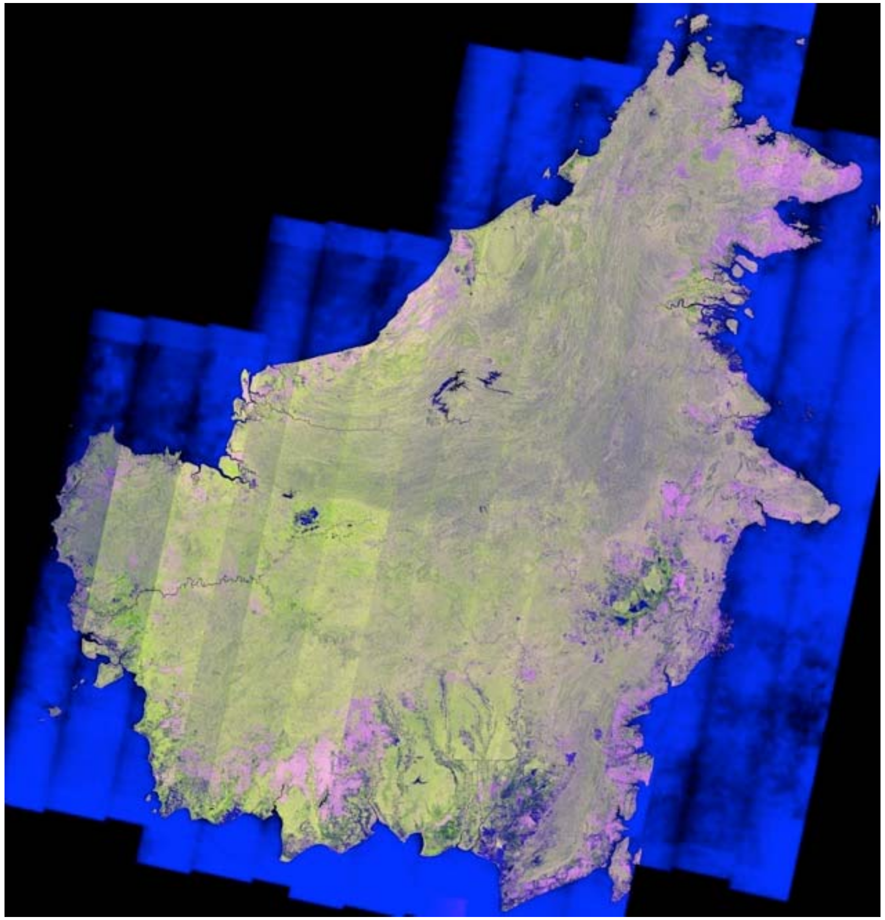
Results and significant findings thus far

Describe project outcomes and significant findings to date (several slides OK!)

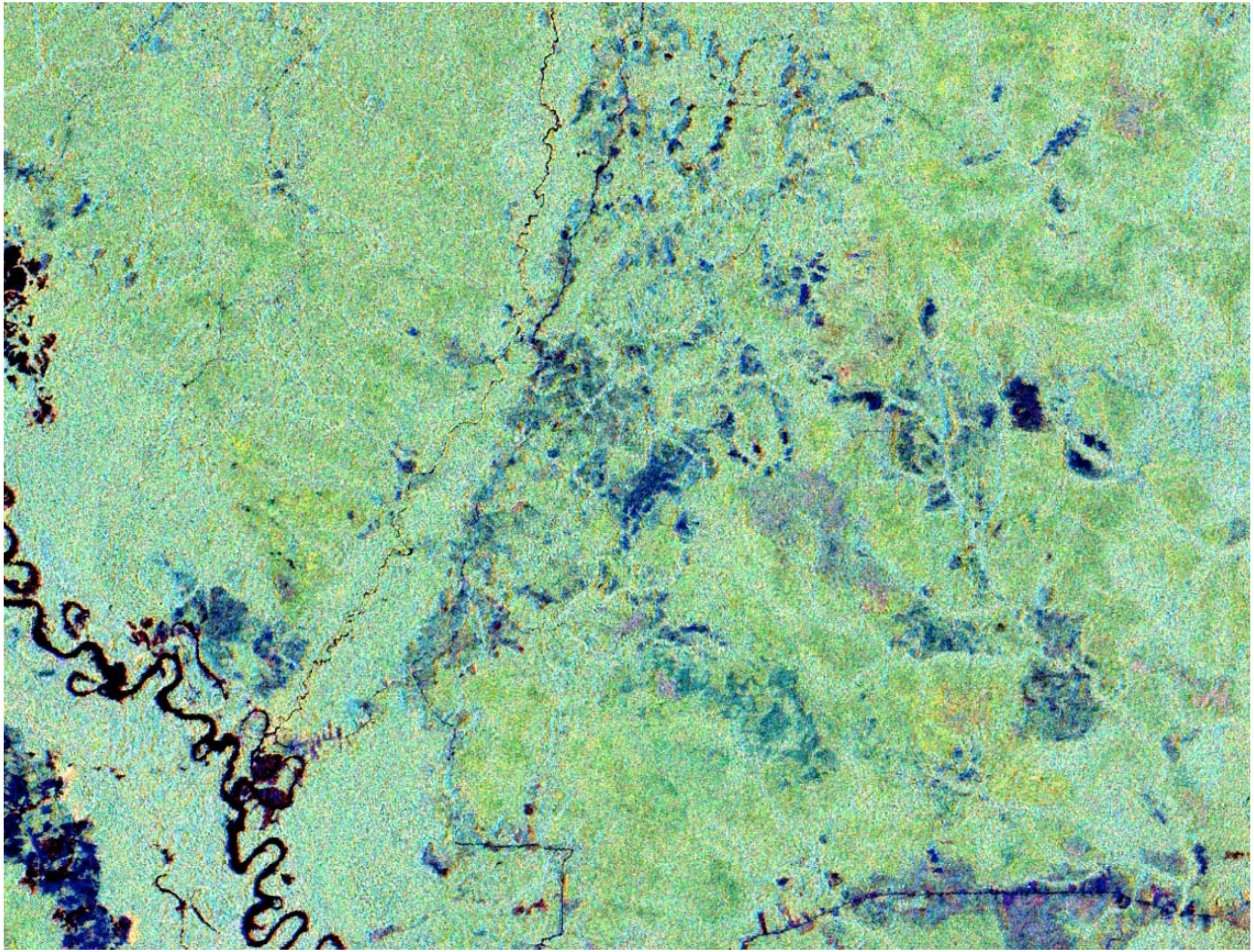
1. Combining PALSAR-2 and Sentinel-1



PALSAR-2 mosaic data
2014-2015



Sentinel-1 mosaic
2014 - 2015 (7 dates)

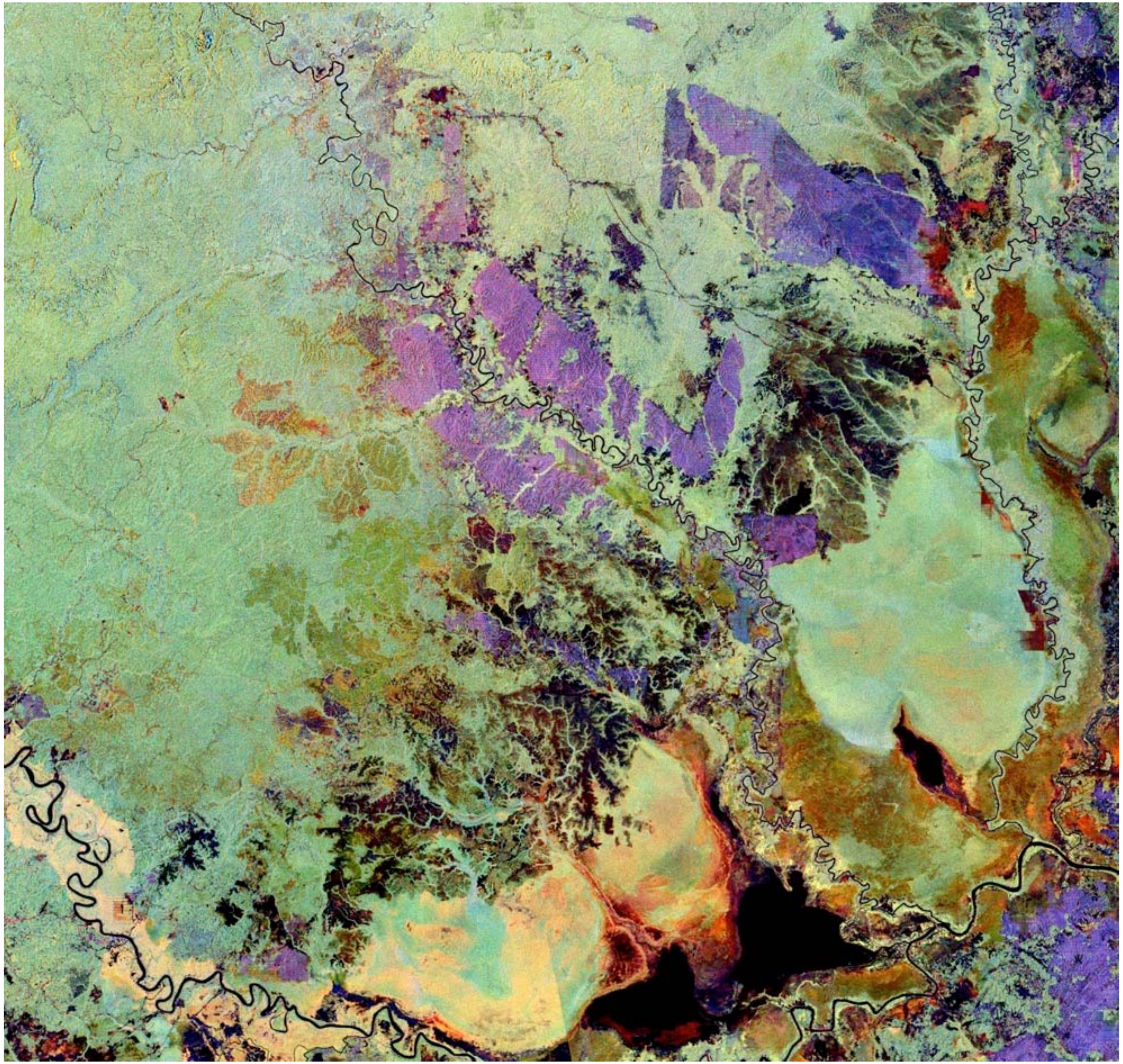


Kerangas forest

- Palsar-2
- Sentinel-1
- Combined

S1A_PLSR2_
HH_HVVH_VV

Improved forest stratification

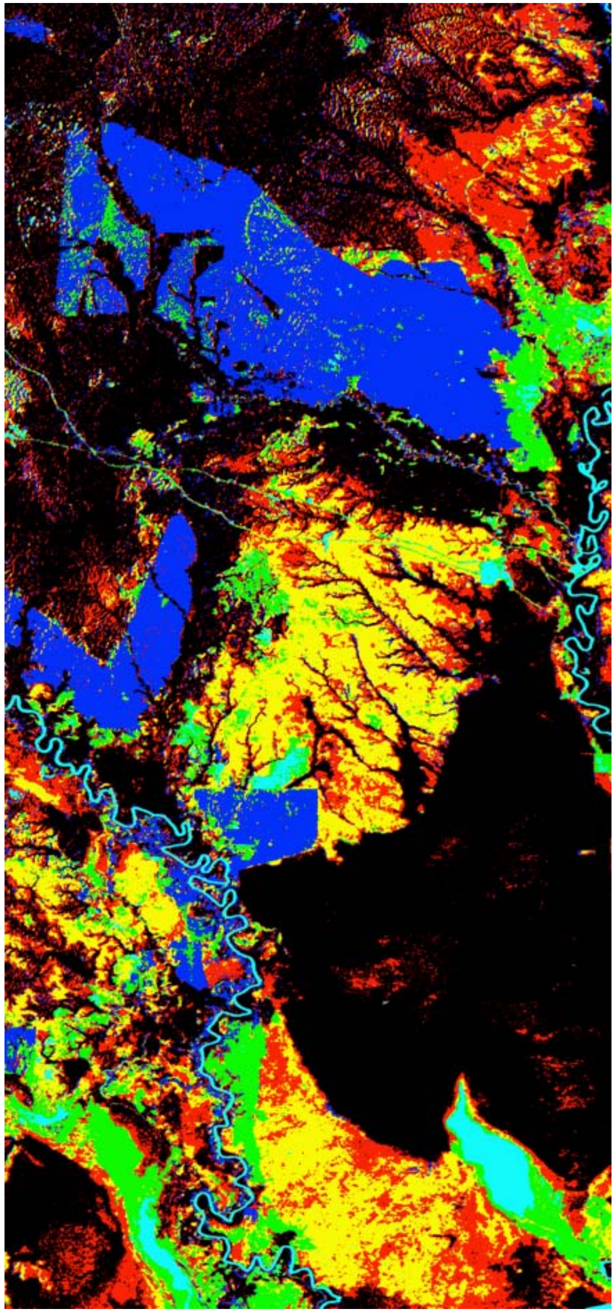


Oil Palm development

•Palsar-2
•Sentinel-1
•Combined

S1A_PLSR2_
HH_HVVH_VV

Improved oil palm strata classification



Unsupervised classification test for REA area, East Kalimantan

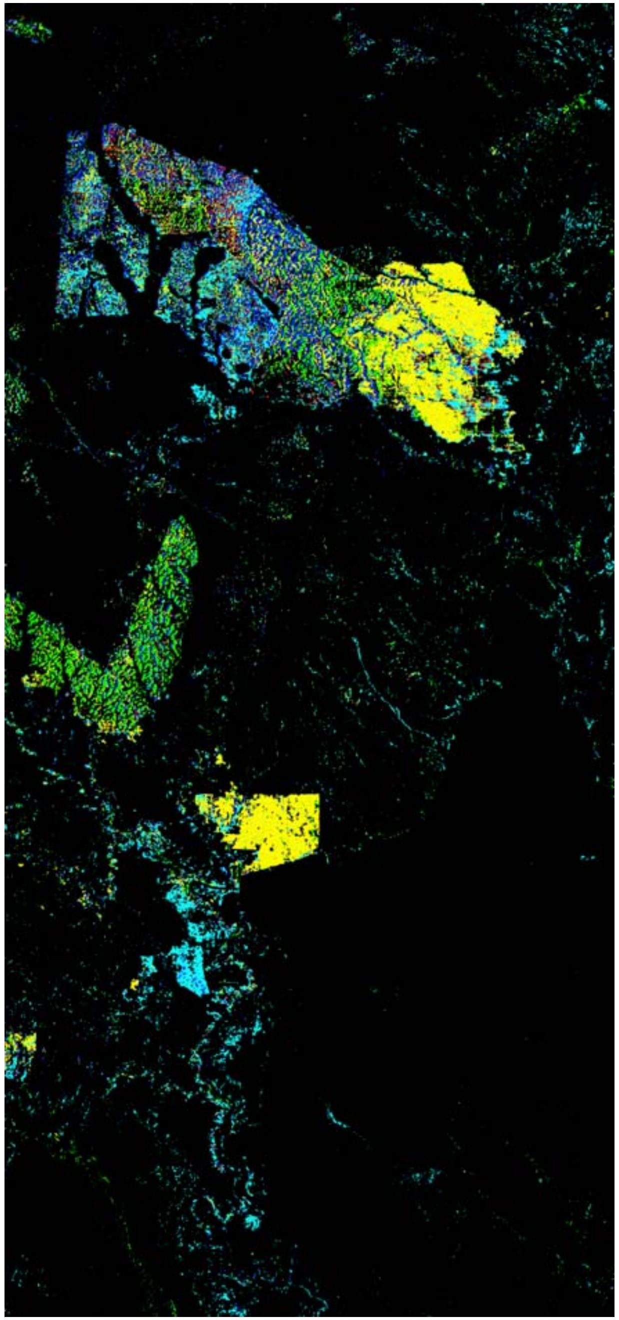
1.PALSAR-2 only
2.Sentinel-1 only
3.PALSAR-2 & Sentinel-1

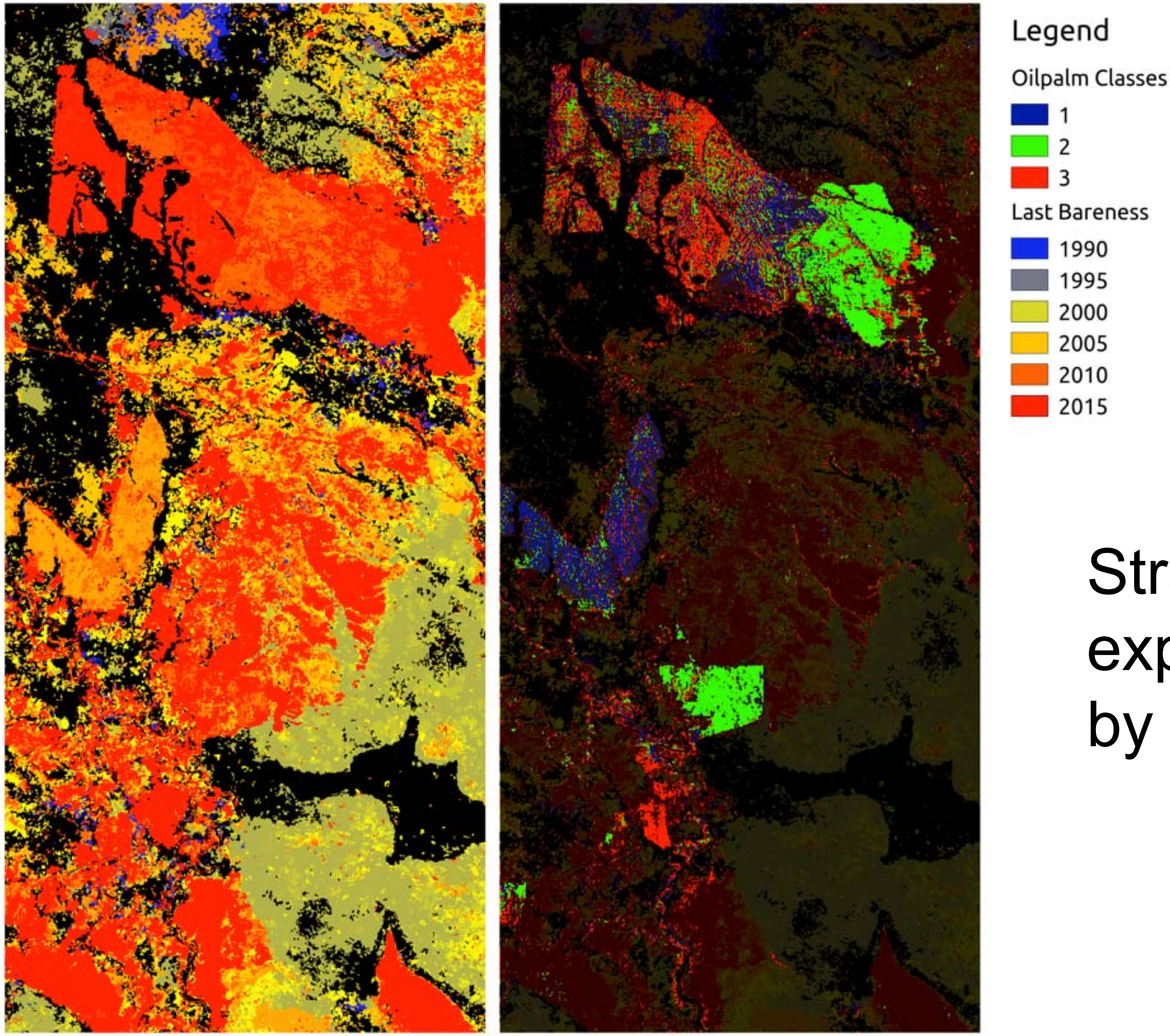
Classification results are best for the combination

Unsupervised classification test for REA area, East Kalimantan

1. PALSAR-2 only
2. Sentinel-1 only
3. PALSAR-2 & Sentinel-1

Stratification results are best for the combination



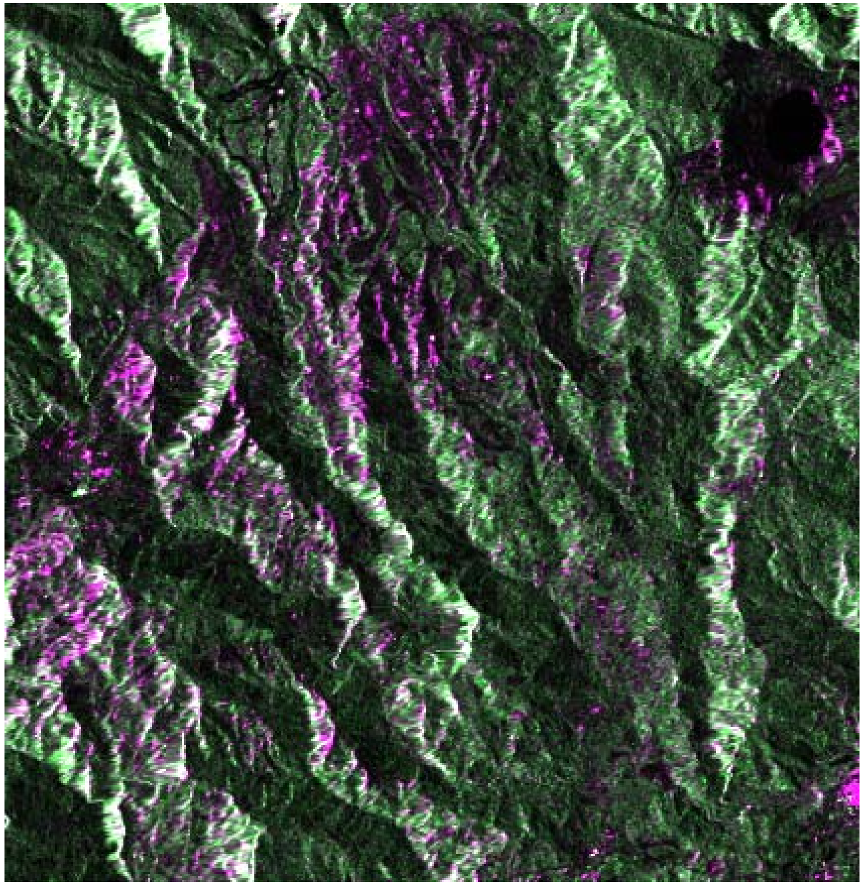


Year of last bare soil detection

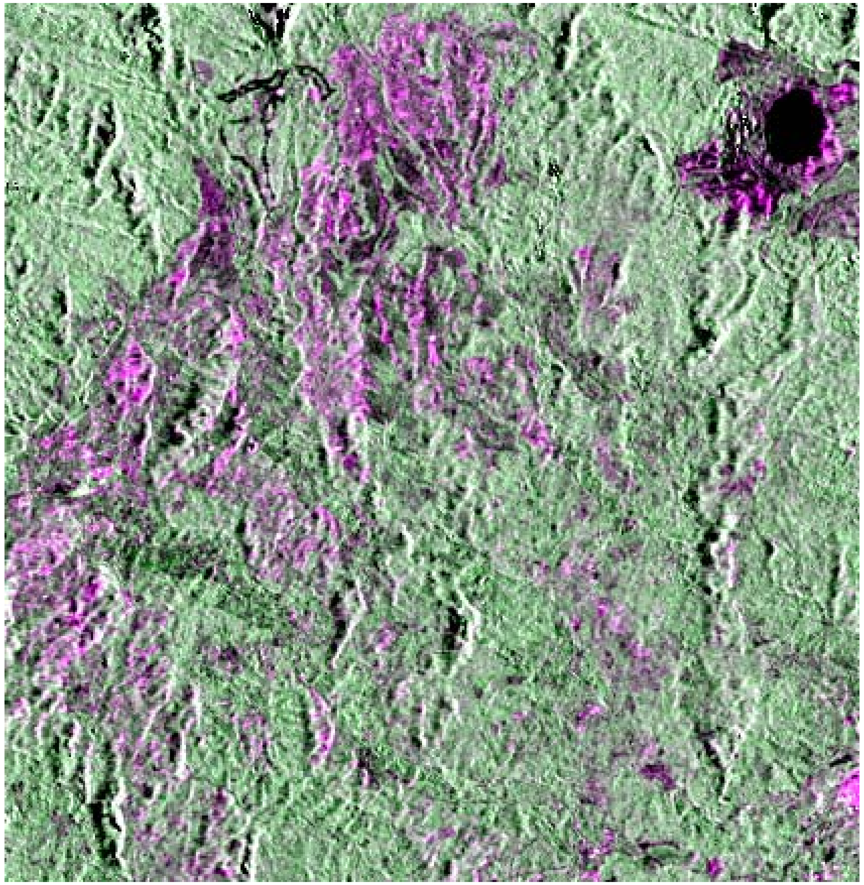
Stratification can be explained to large extent by soil type and age

2. Large area multi-model slope correction

Multi-model slope correction FBD 25m path image mosaic entire Borneo



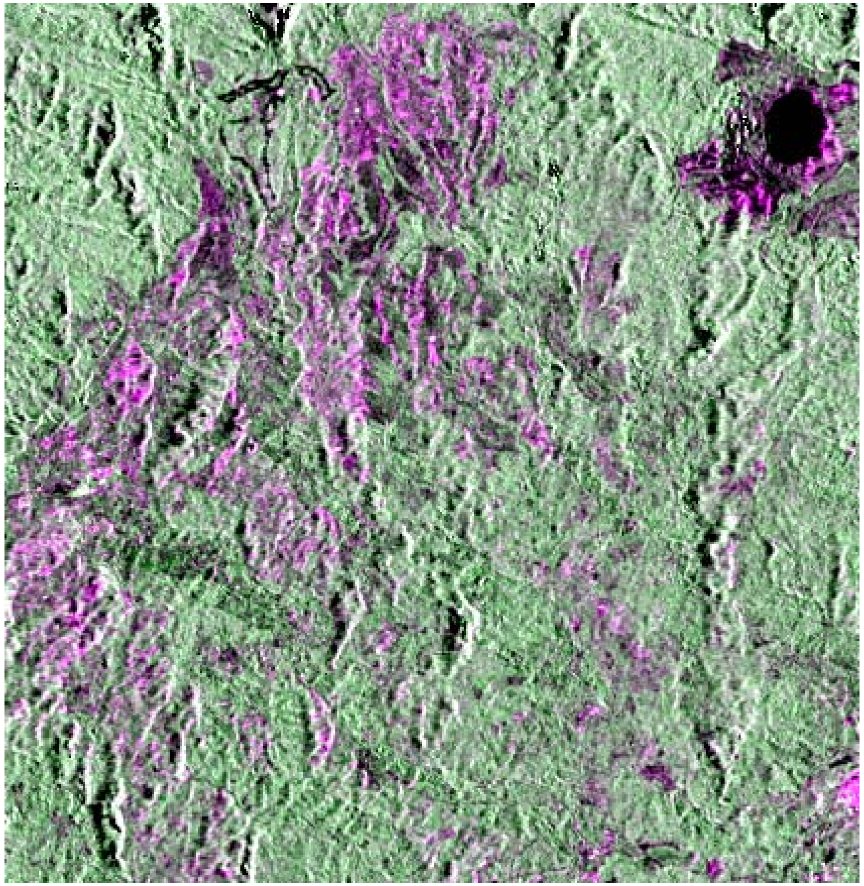
No slope correction



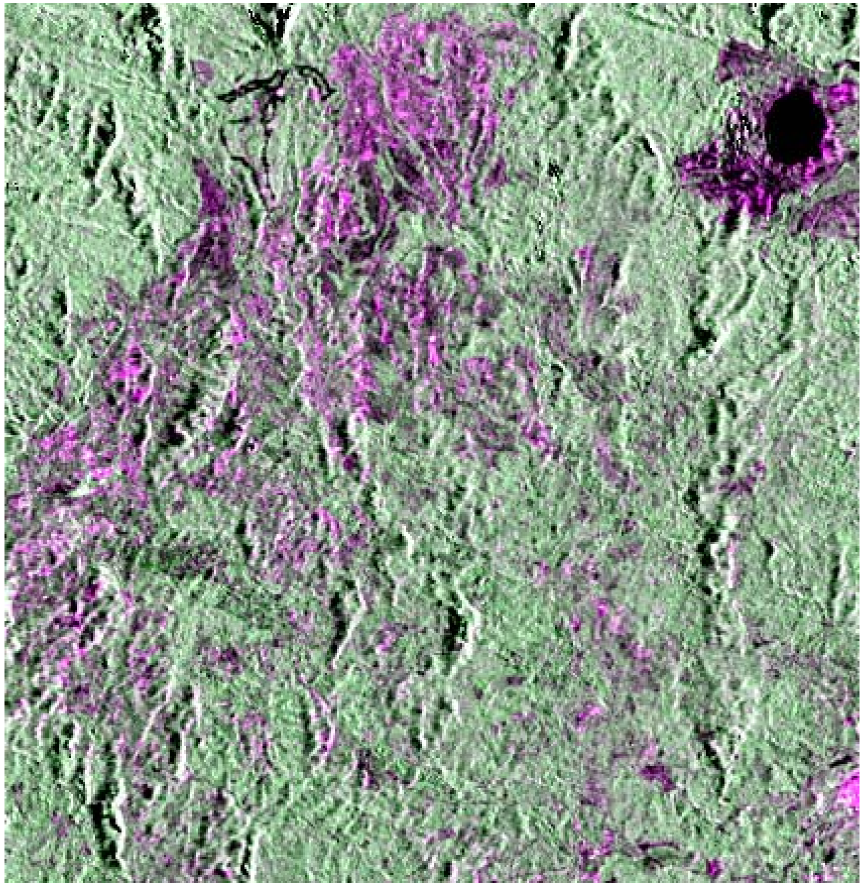
Slope model 1

Using SRTM 30m pixel data (60 m resolution) most slope effects are mitigated with a simple model. Note that short steep hills are still prominent.

Multi-model slope correction FBD 25m path image mosaic entire Borneo



Slope model 1

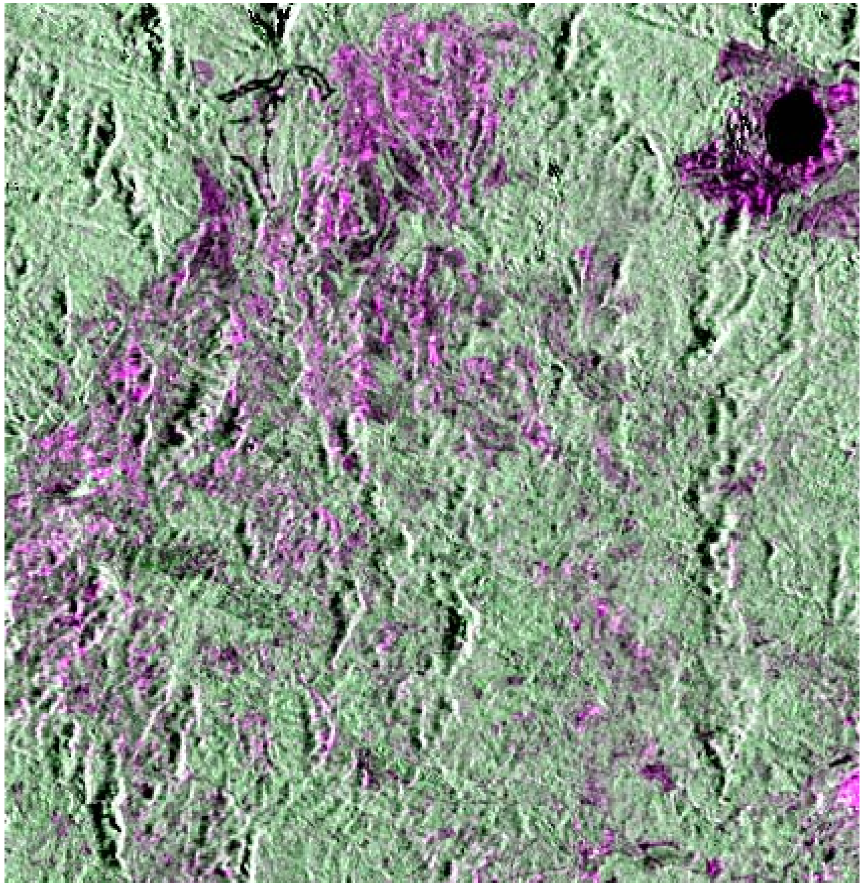


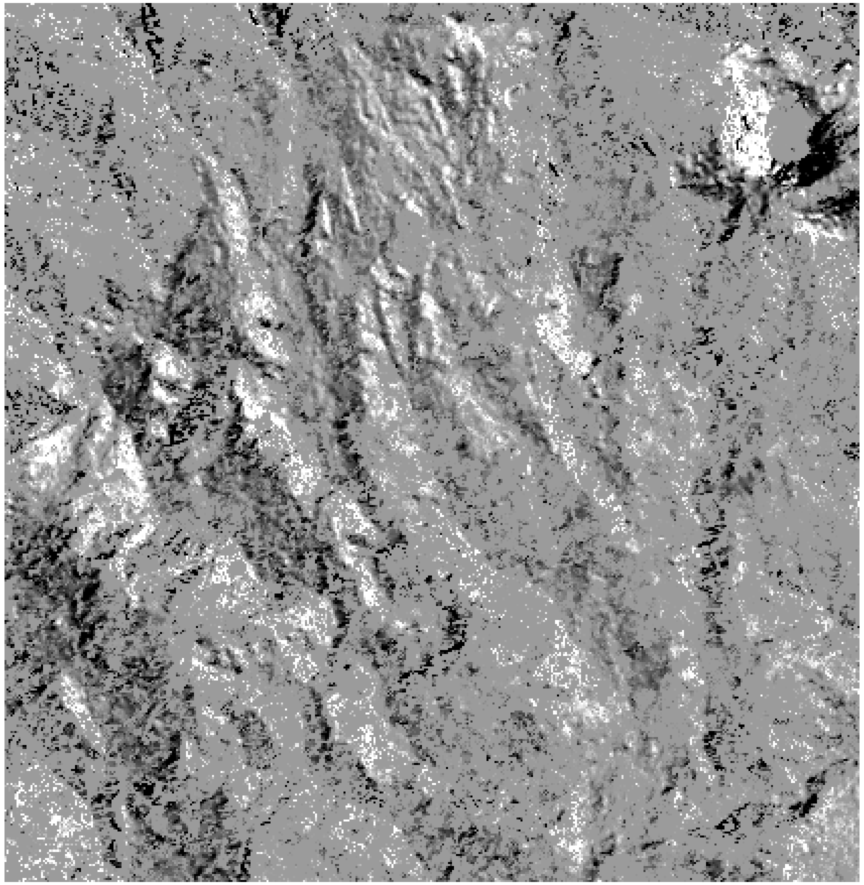
Slope model 3

Model 3 gives further improvement. Typical changes on slopes in areas with sparse vegetation up to ±1 dB

For biomass mapping this corrects errors up to ±40%

Multi-model slope correction FBD 25m path image mosaic entire Borneo

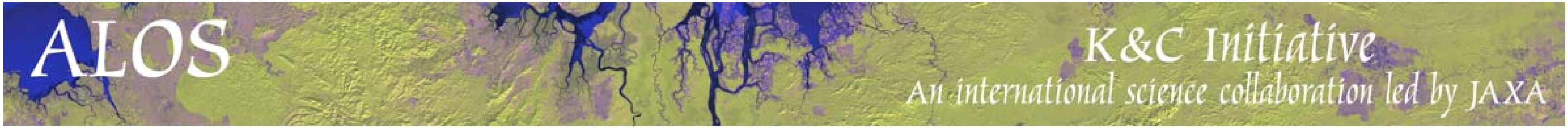




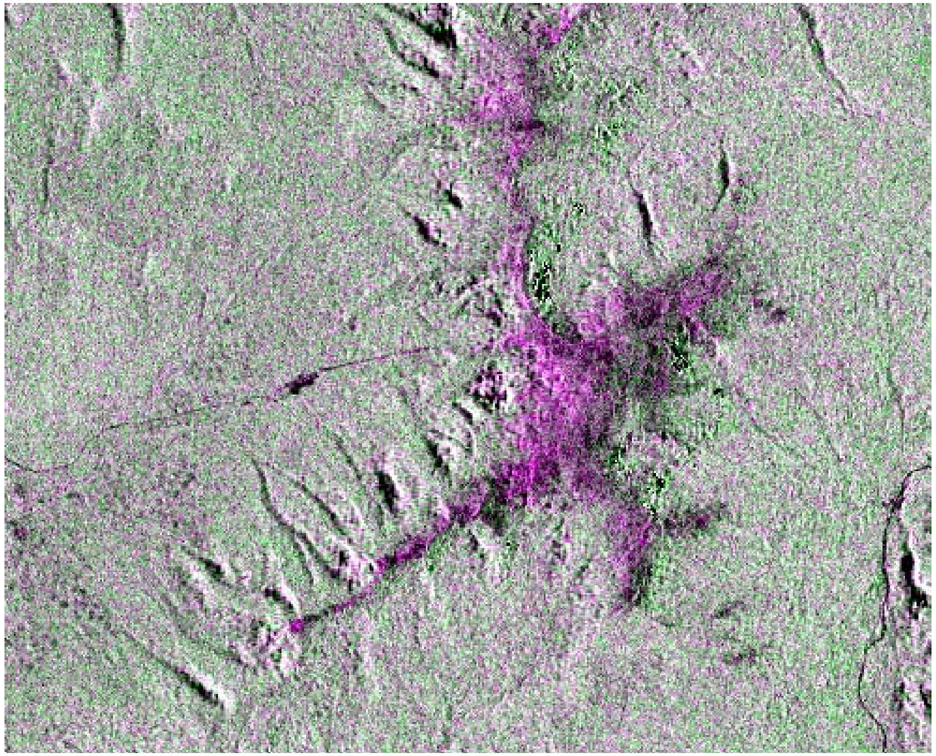
For RSP414 5% of the pixels were corrected with a value of ≤-0.25 dB (facing slopes) and 0.4% of the pixels with ≥ 0.25dB (back slopes).

Slope model 1<>3

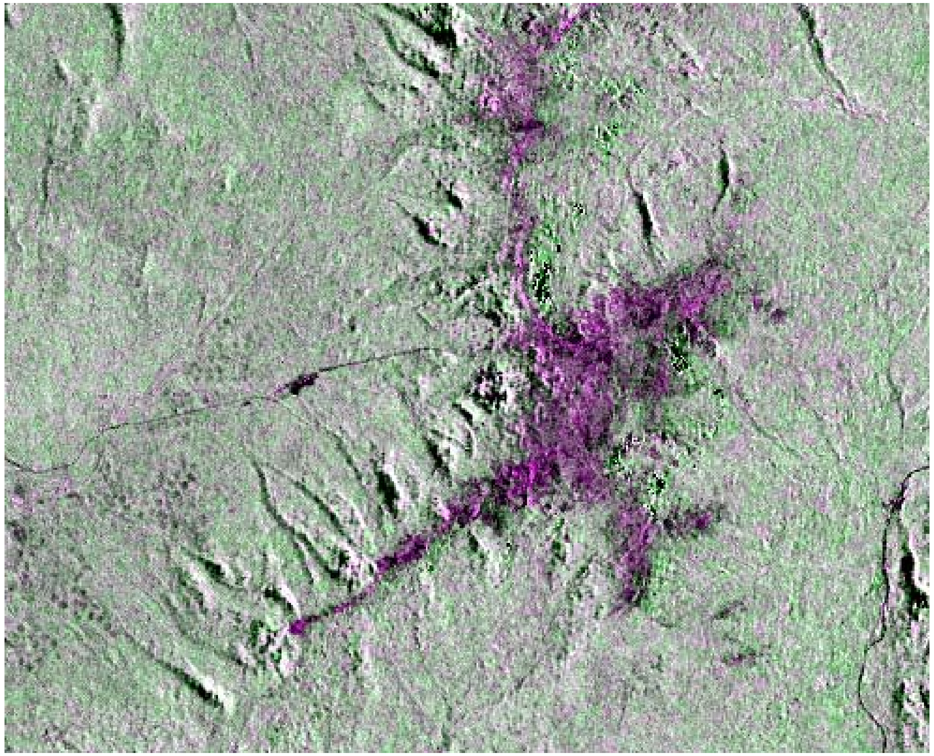
Correction applied for HV



PALSAR New Hampshire:
Models work with almost identical settings



Original image: orthorectified and slope corrected



With 2nd order slope correction

3. Wetlands mapping Borneo

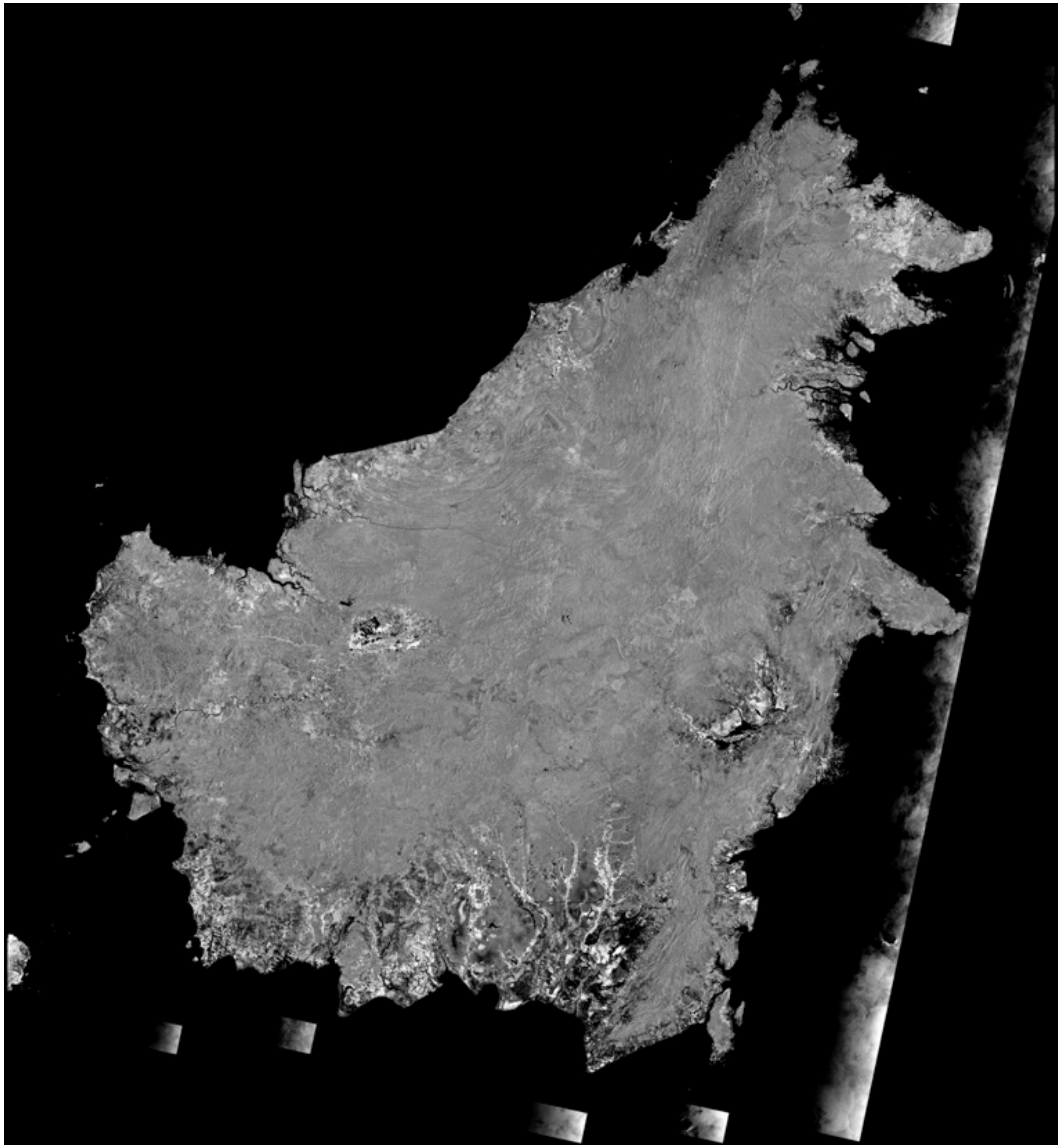
Automation for entire Borneo

It is pursued to develop a fully automated approach based on PALSAR data only.

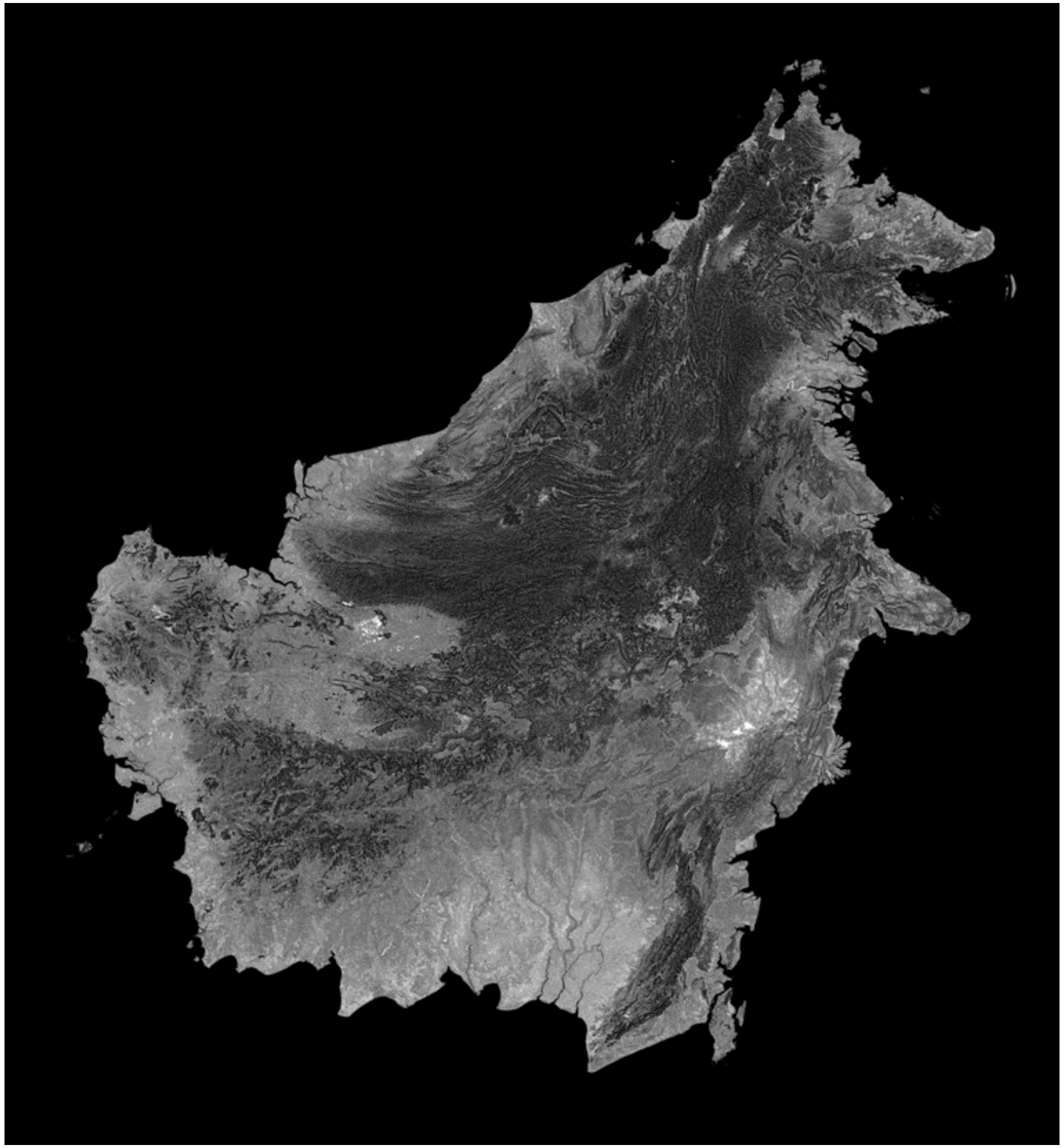
All WB observation (±60-40 per pixel in the PALSAR-1 period) have been processed into a seamless map of the entire area of Borneo.

These maps show open water flood frequency and flooded vegetation frequency (both scaled between 0 and 100%). The problem of confusion between open water and bare soil (both have very low radar backscatter) has been solved.

Consequently, bare soil frequency can also be mapped. City areas are mapped as well.

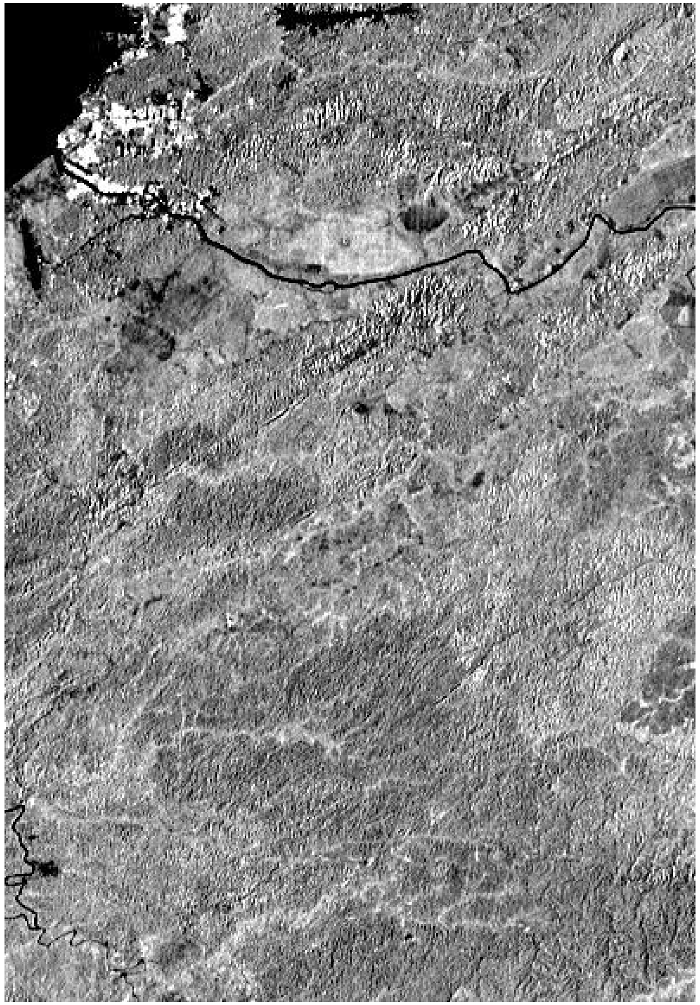


Palsar-1 WB-Av (± 60-40 scenes)

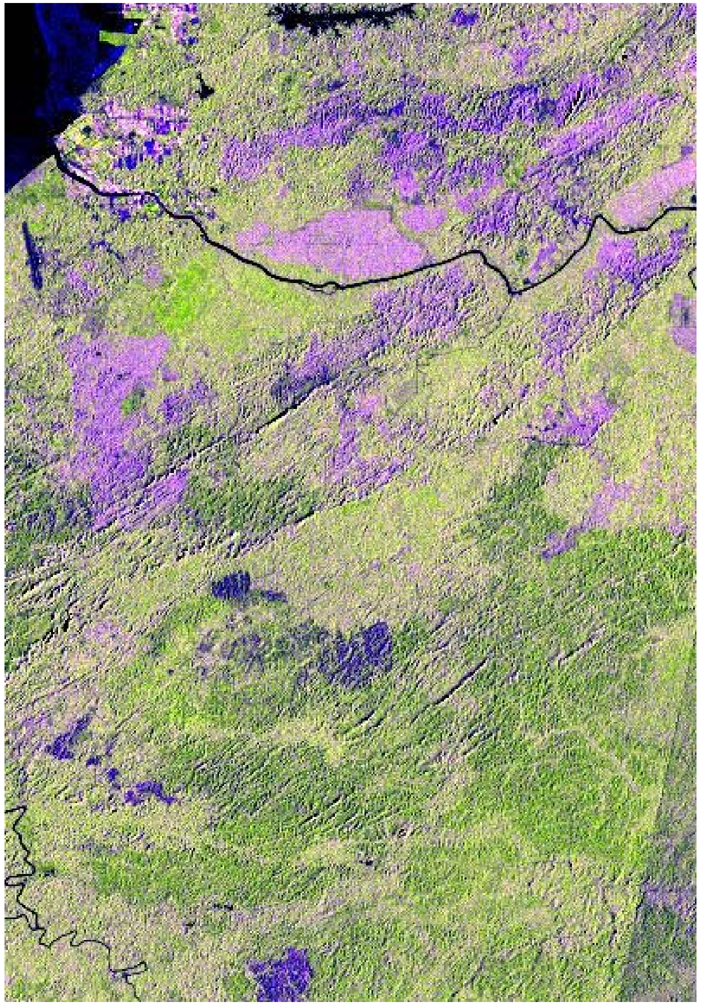


TWI

Sarawak oil palm and acacia plantations

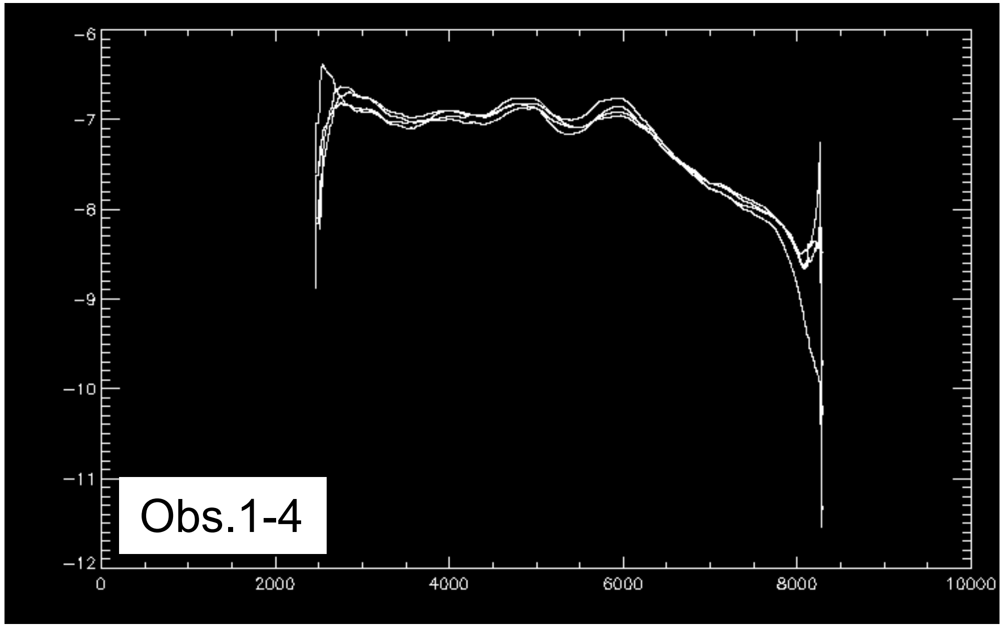


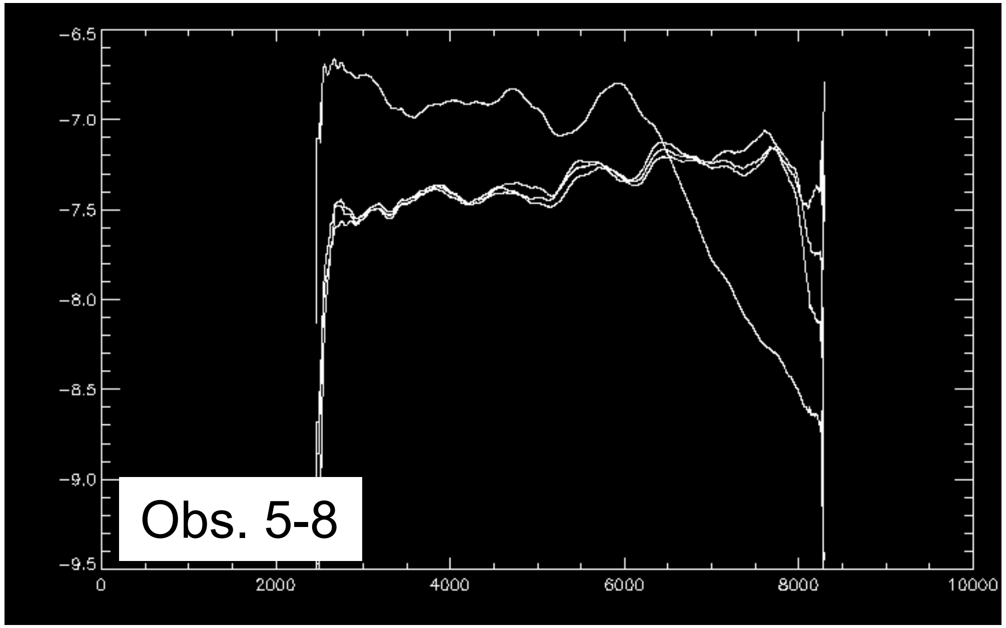
Palsar-1 WB-Averaged
(± 60-40 scenes)

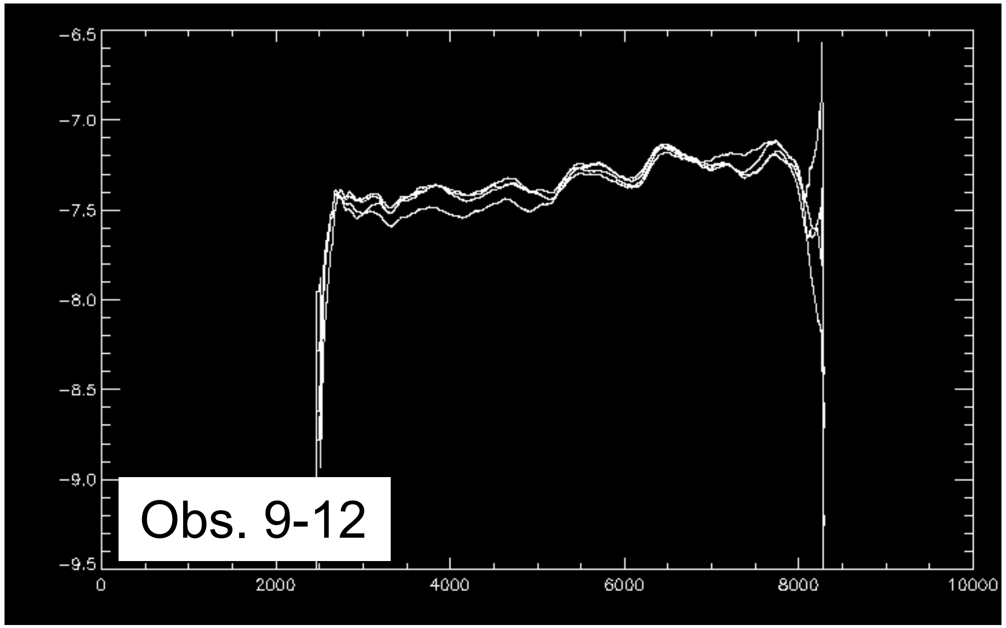


Sentinel-1
VV-HV-VV/HV
Acacia in dark green

S1 VV-HV WB-Av
Blue indicative for acacia plantation extension

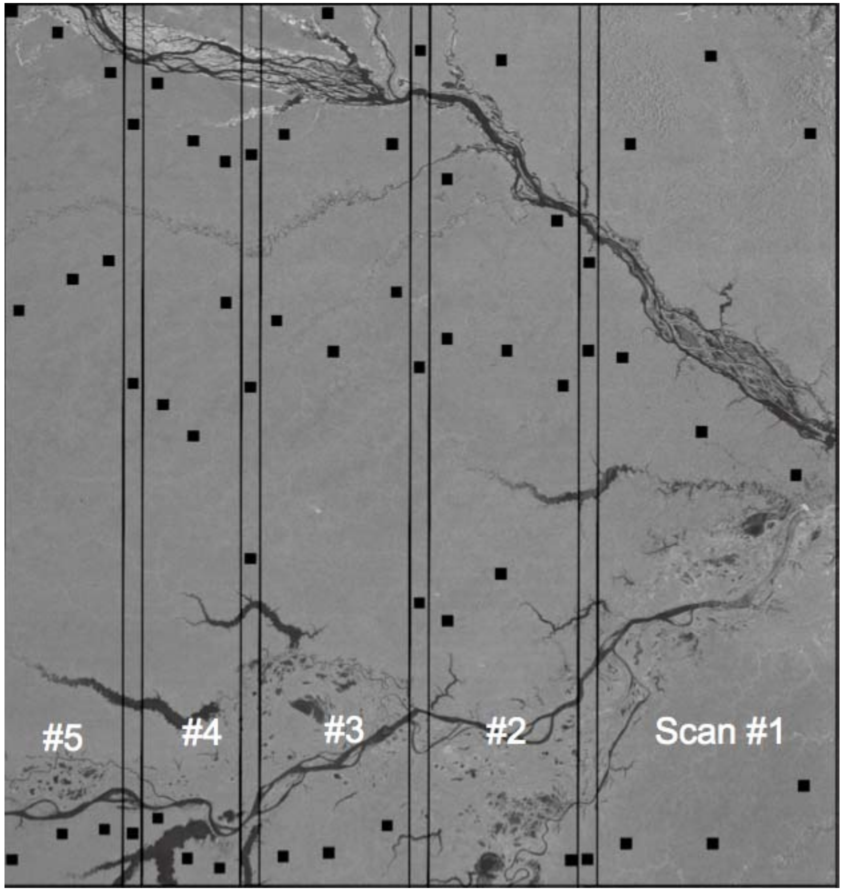




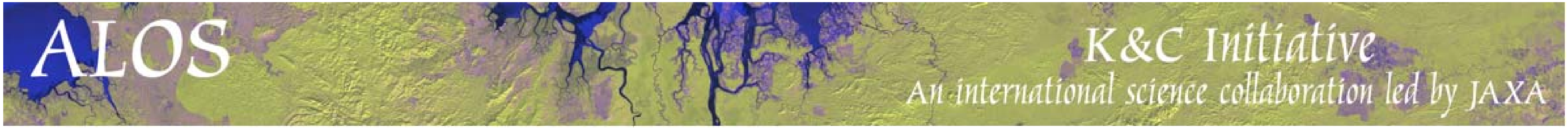


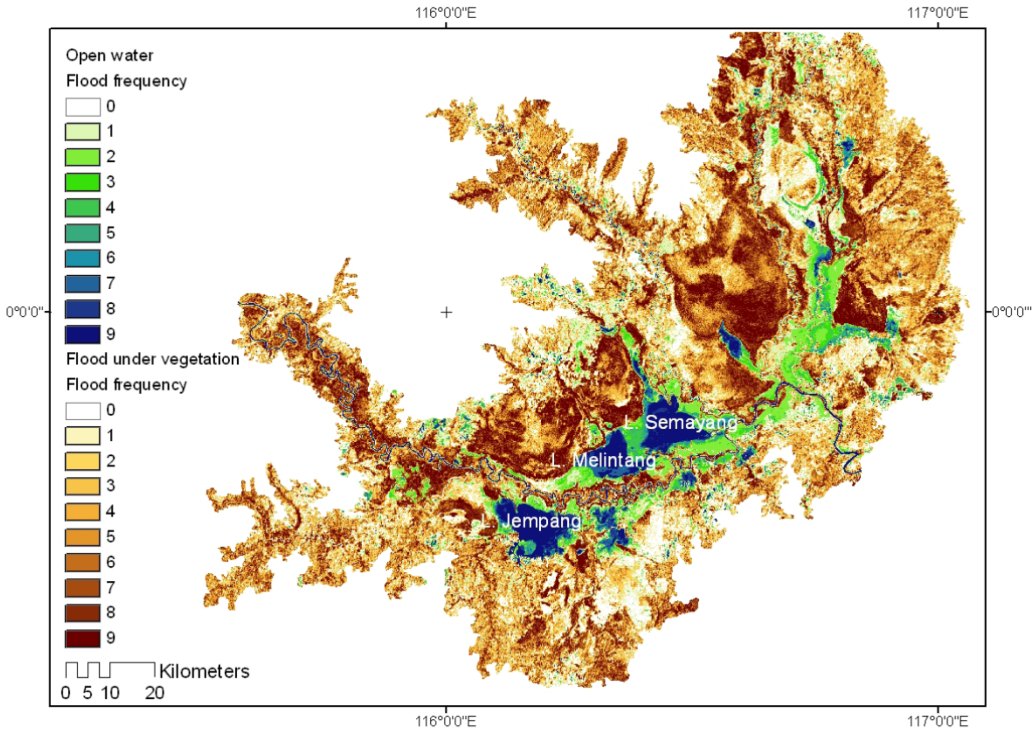
Range profile of WB forest backscatter. Levelling in range was done for individual images.

Sub-beams show varying levels of ENL.



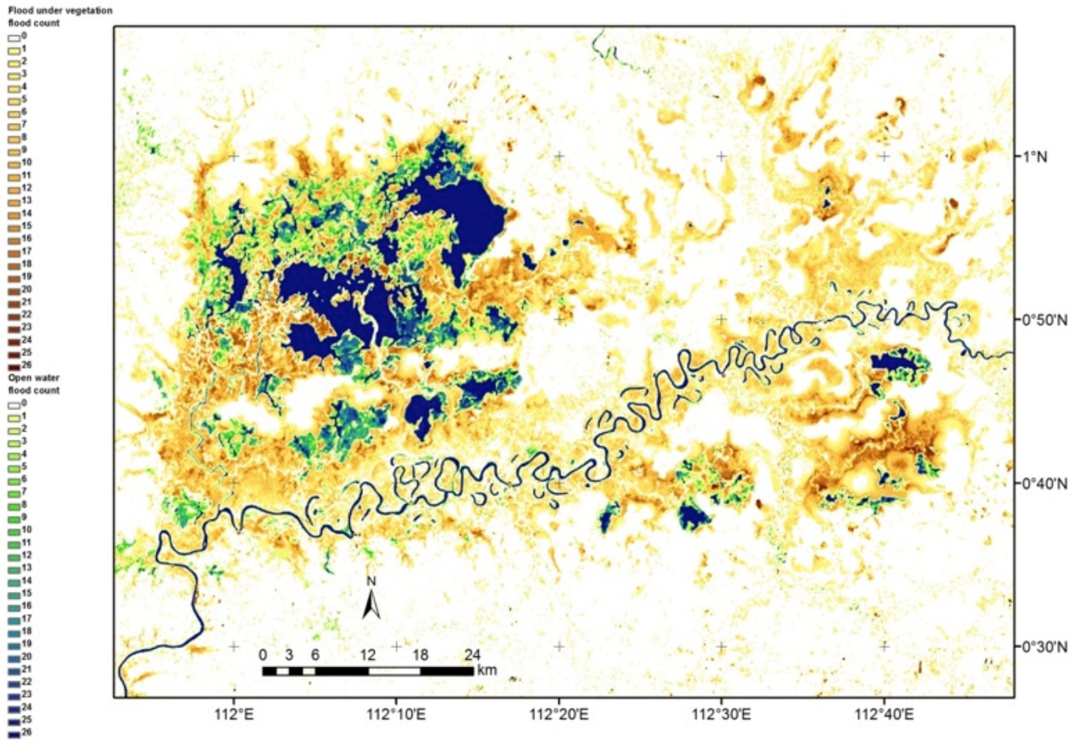
ScanSAR sub-beams. Source: Ake R.





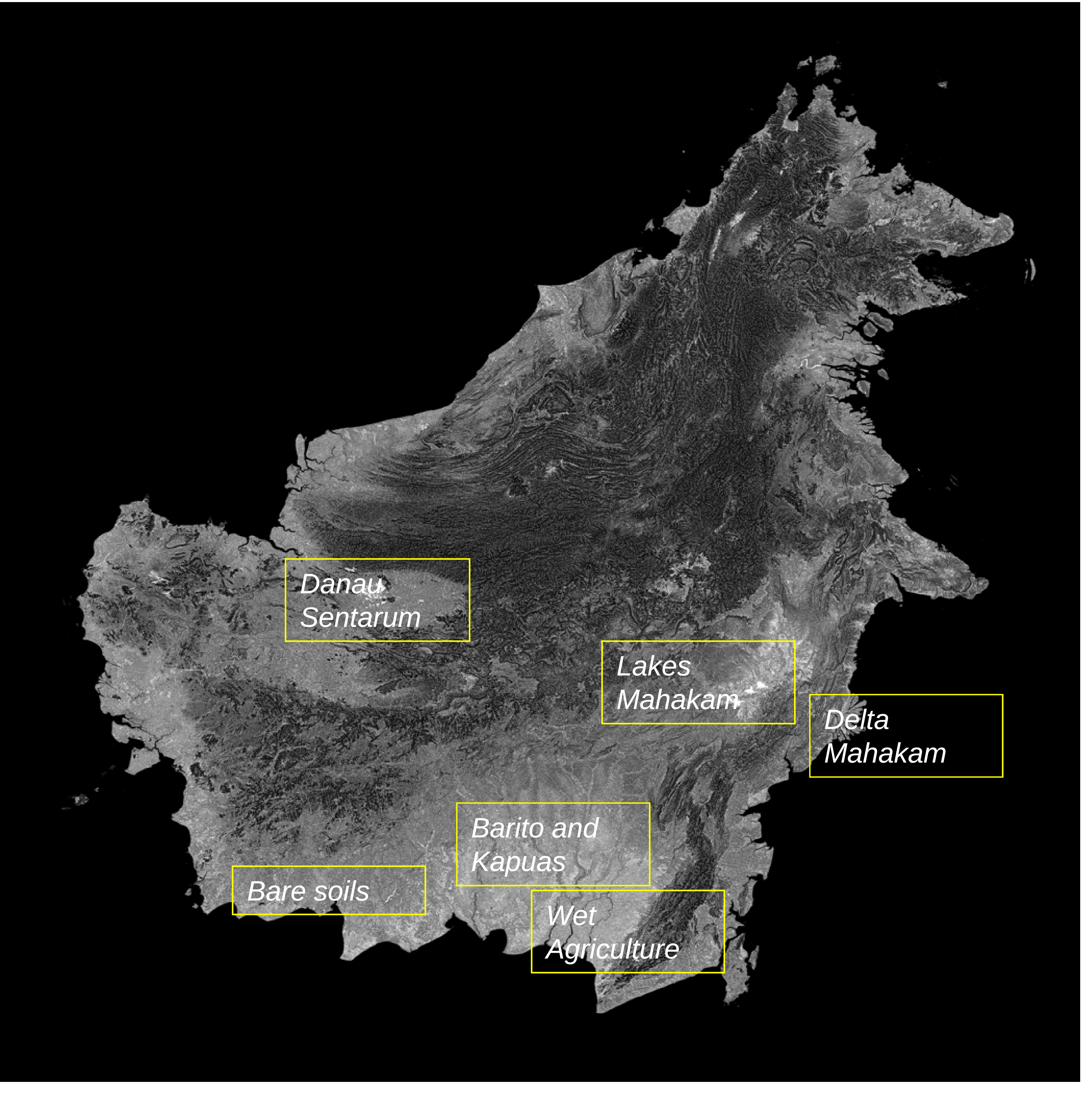
Flood frequency of the **Mahakam watershed** derived from PALSAR ScanSAR images of the 2008-2009 period. Open water (light green – dark blue) and flooding under vegetation (light – dark brown).

Ref. Hidayat, H., D. H. Hoekman, M. A. M. Vissers, and A. J. F. Hoitink, 2012, Flood occurrence mapping of the middle Mahakam lowland area using satellite radar. *Hydrology and Earth System Sciences*, Vol.16, pp.1805-1816.



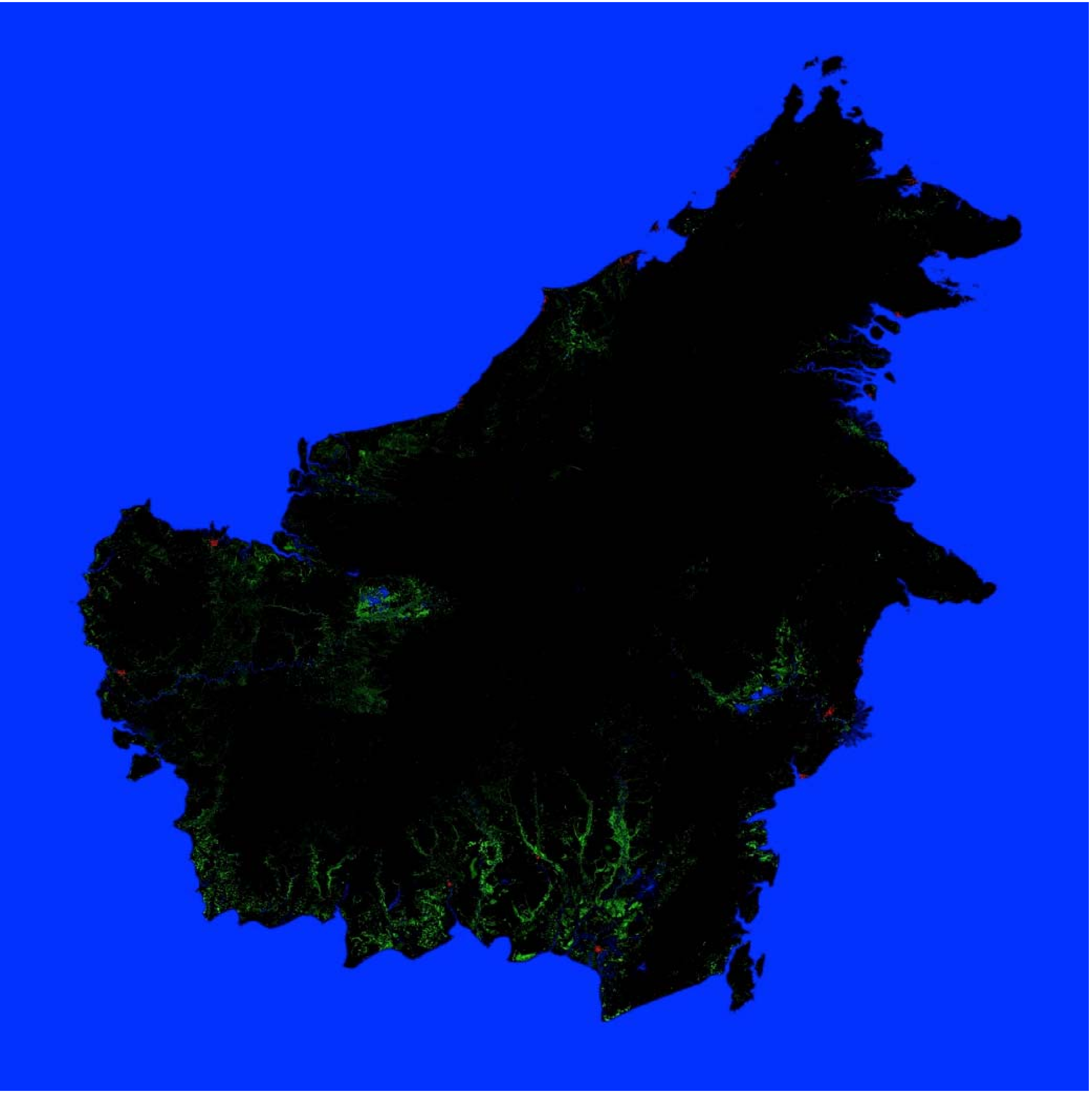
Flood frequency in the **Upper Kapuas area** derived from PALSAR ScanSAR images of the 2007–2010 period.

Ref. Hidayat, H., D. H. Hoekman, M.A.M. Vissers, Md. Monowar Hossain, A.J. Teuling, G.S. Haryani, 2014, Inundation mapping of the upper Kapuas wetlands using time series of radar images, *Int. Conference on Ecohydrology*, Yogyakarta, November 2014.



Borneo flood frequency map – Base data overview

Examples for the areas indicated will be shown in the next sheets



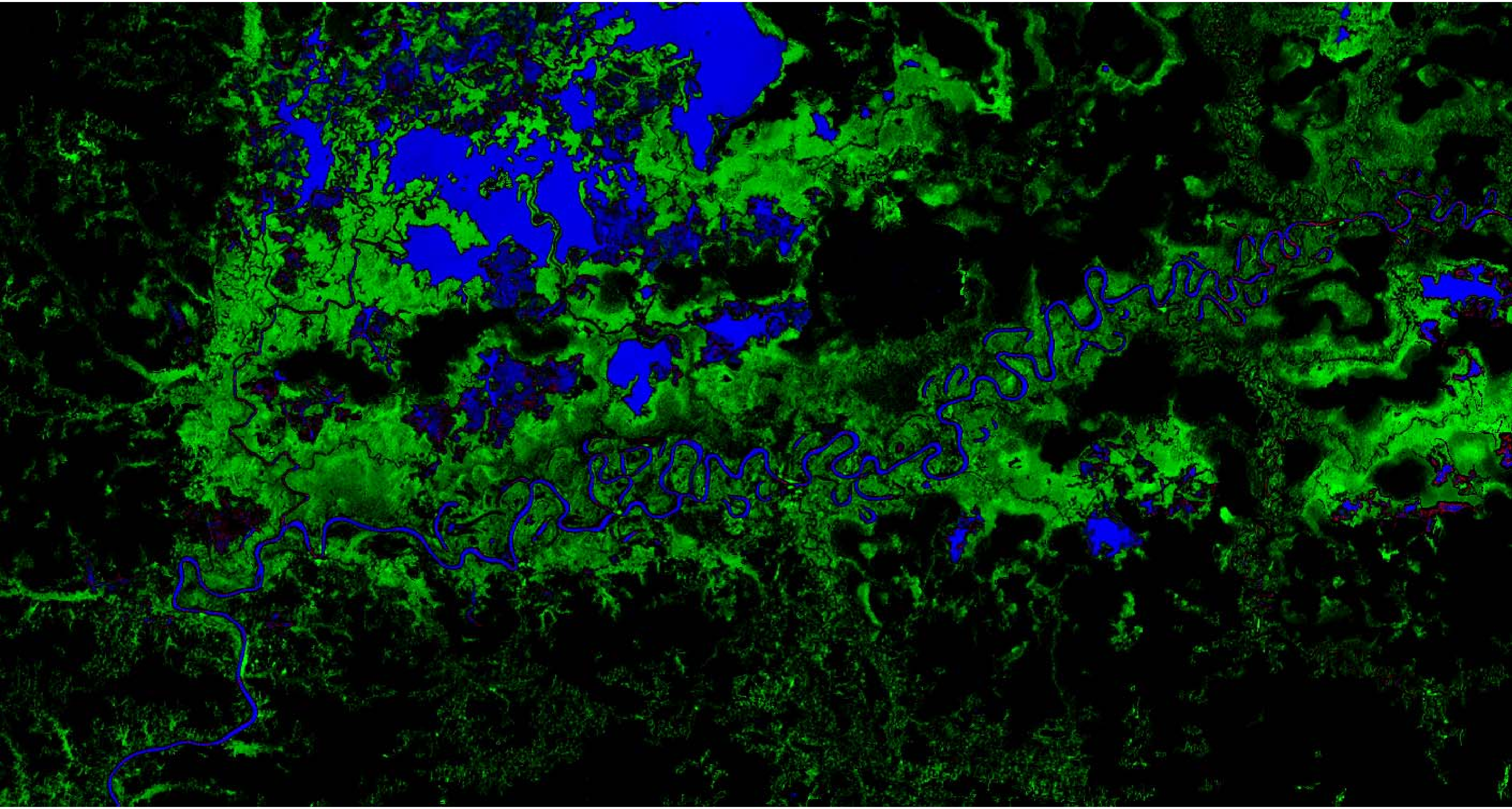
Borneo flood frequency map – Base data overview

This version of the map shows basic continuous colours. Colours such as shown in the published map above (for discontinuous frequency classes) will be added in the final map production stage.

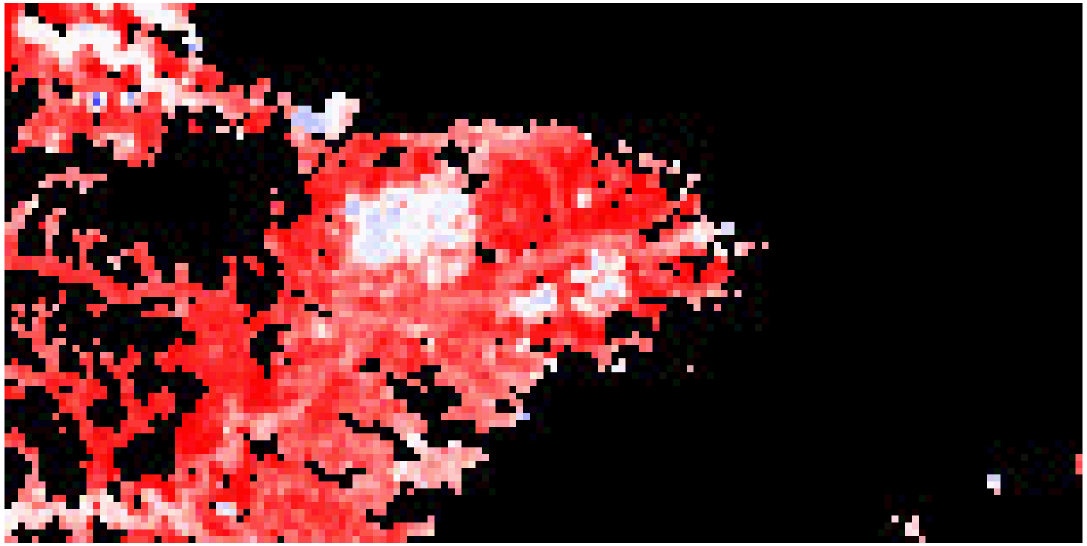
Pixel size: 70mx70m

Legend

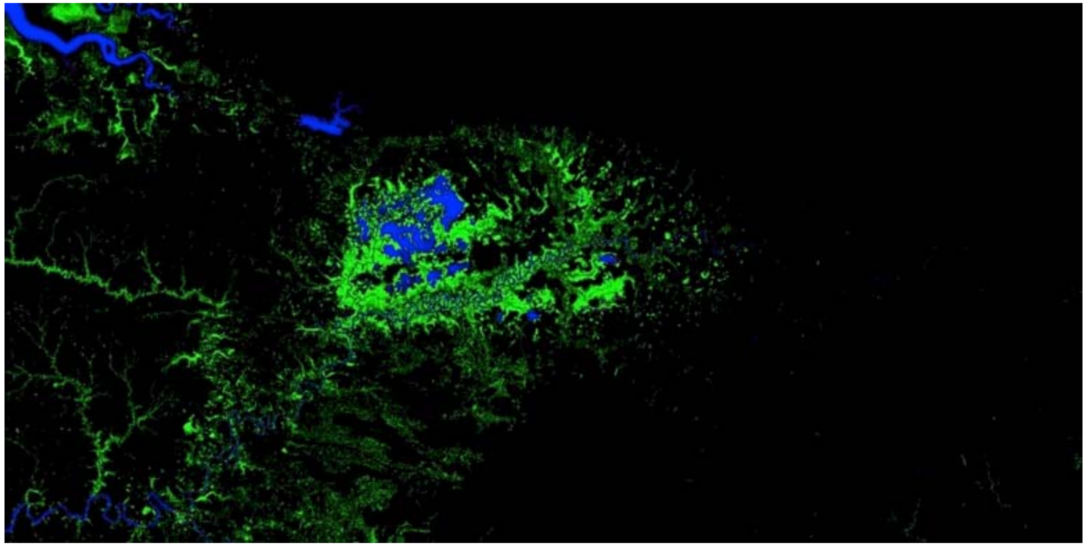
- •Blue: Open water frequency (0-100%)
- •Green: Flooded vegetation frequency (0-100%)
- •Red 1: Bare soil frequency (0-100%)
- •Red 2: City



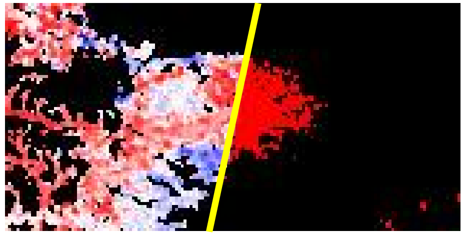
Sentarum lake area in Upper Kapuas



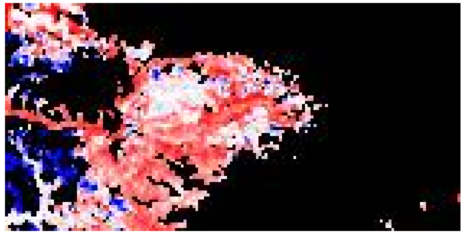
Wetness/dryness dynamics RSP097



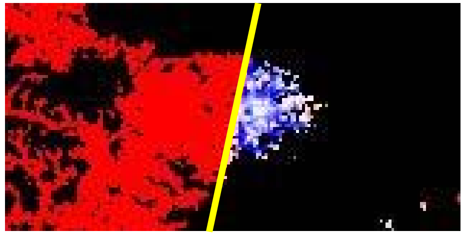
Flood frequency RSP094/097/100



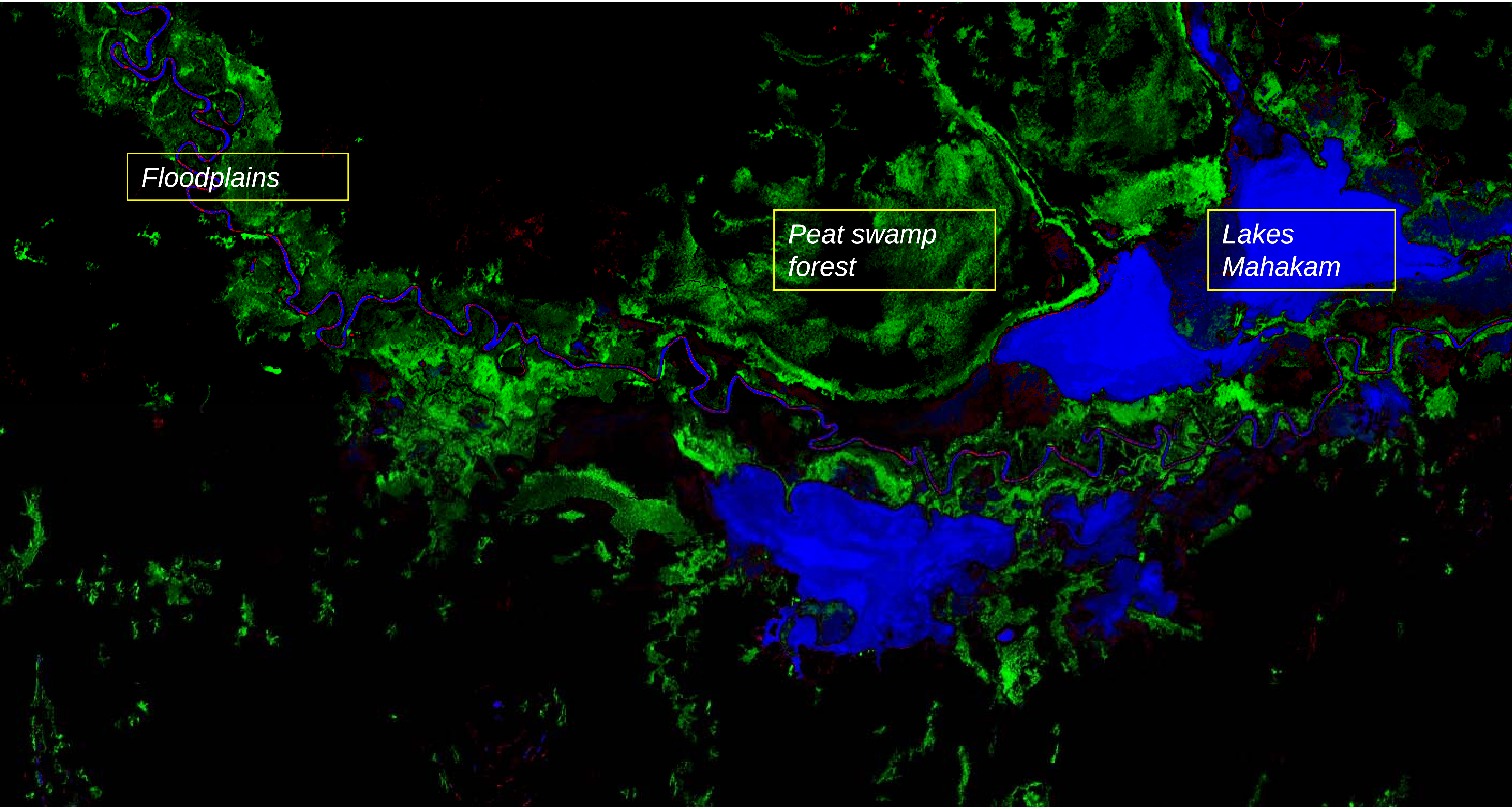
RSP100



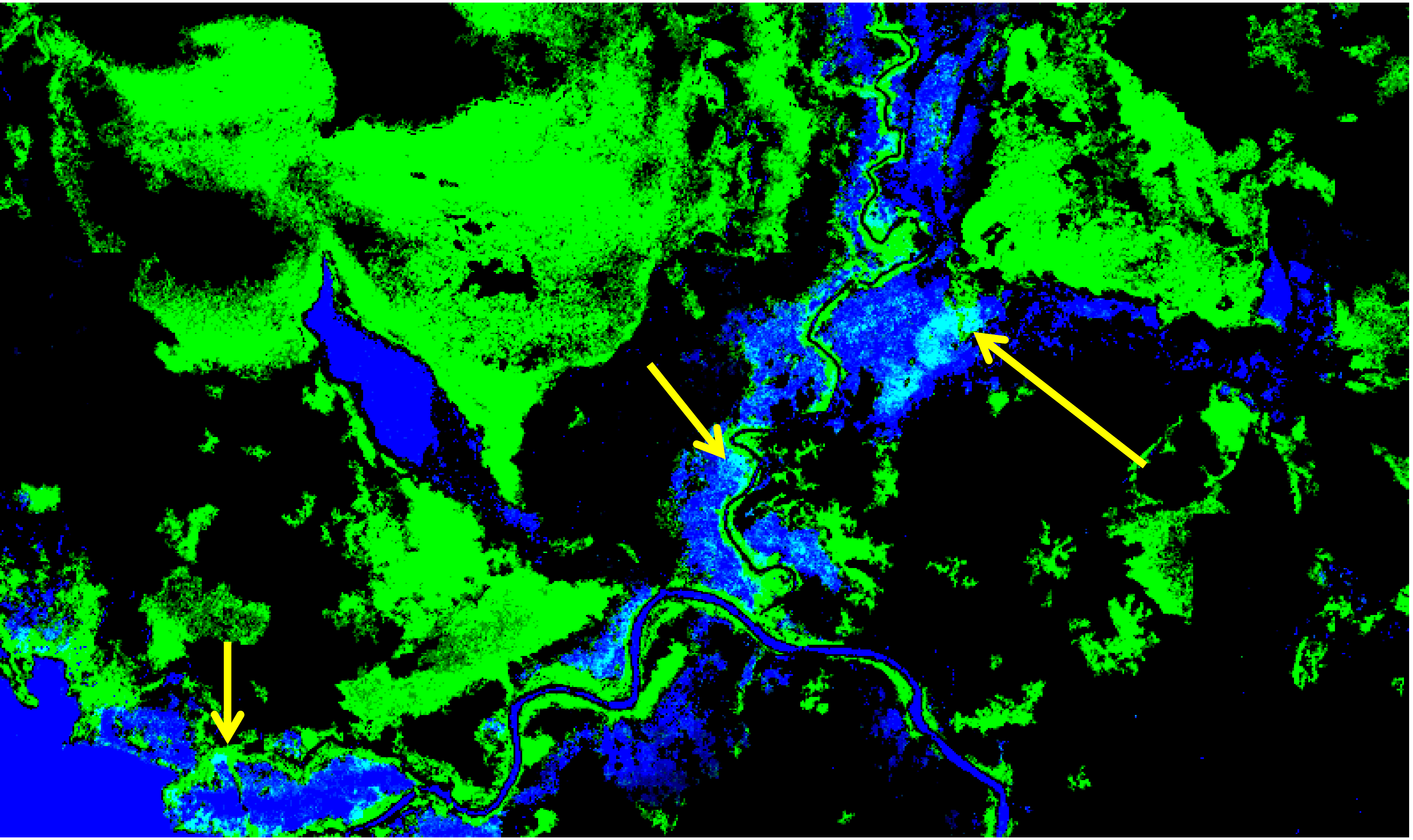
RSP097



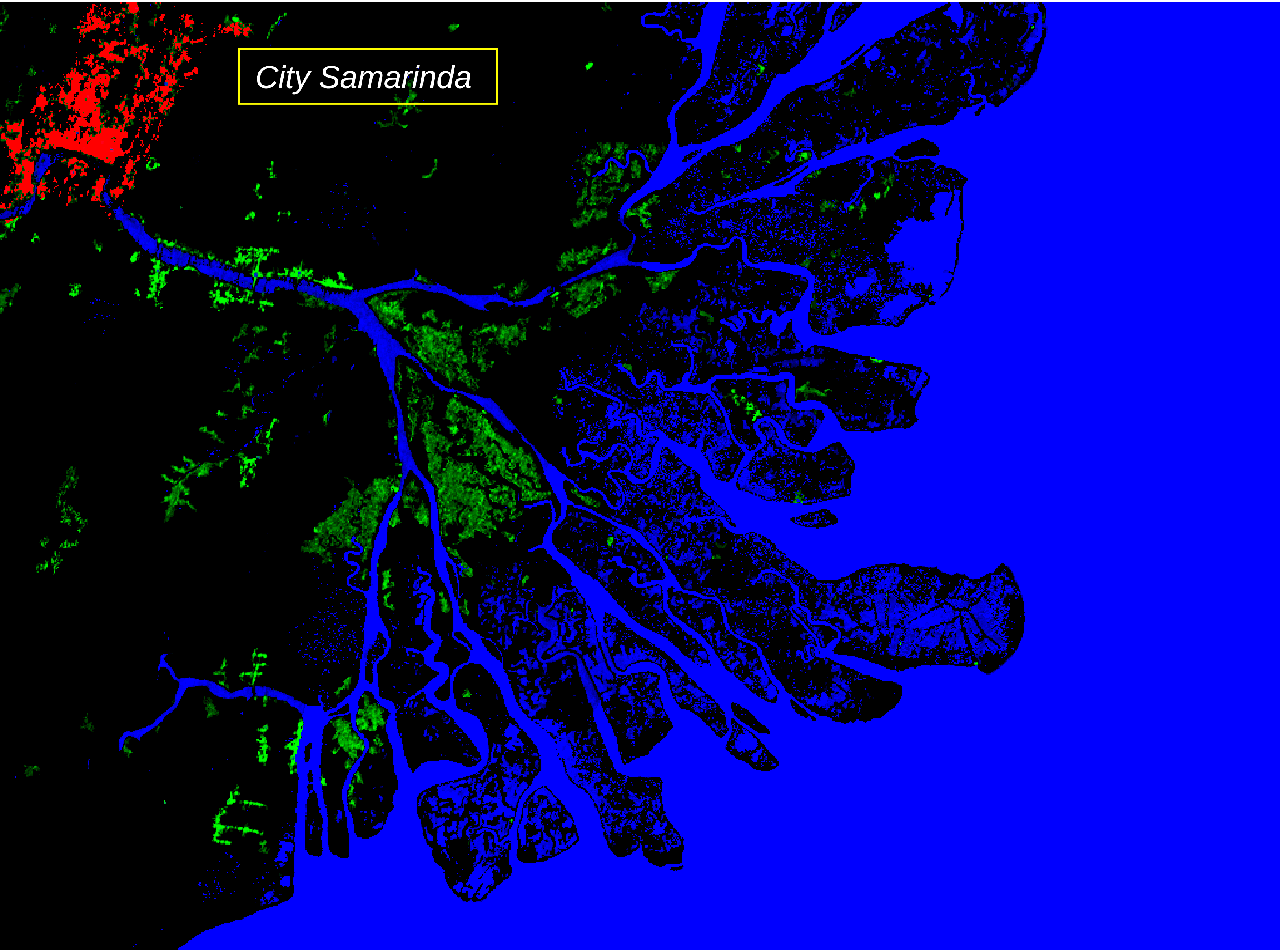
RSP094



Mahakam lake area

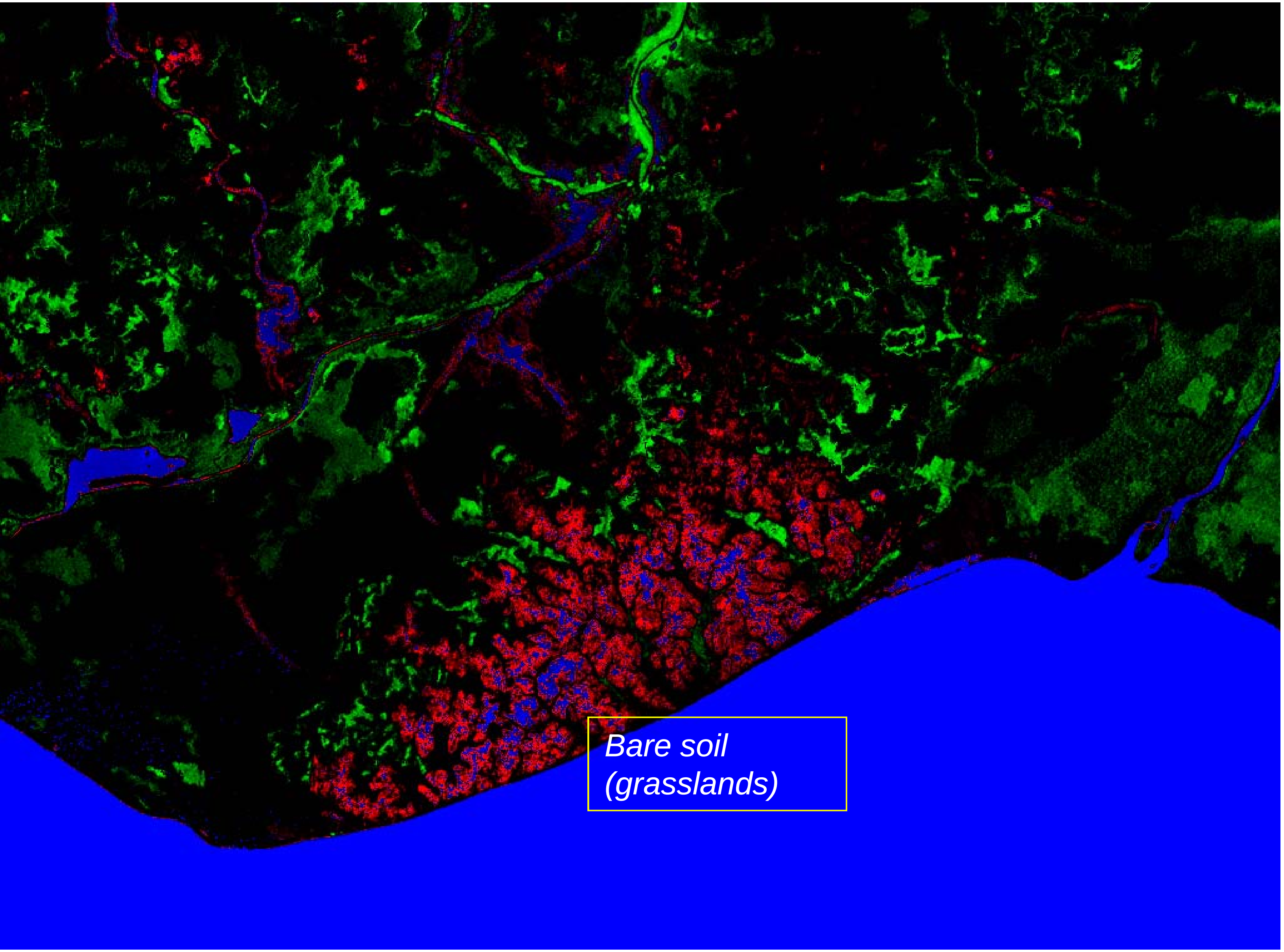


Same area, different spatial and colour scaling. Note that Mahakam river level varies over 8 meters. Cyan area shows flooded vegetation (i.e. flooding under vegetation) as well as open water (vegetation fully submerged).



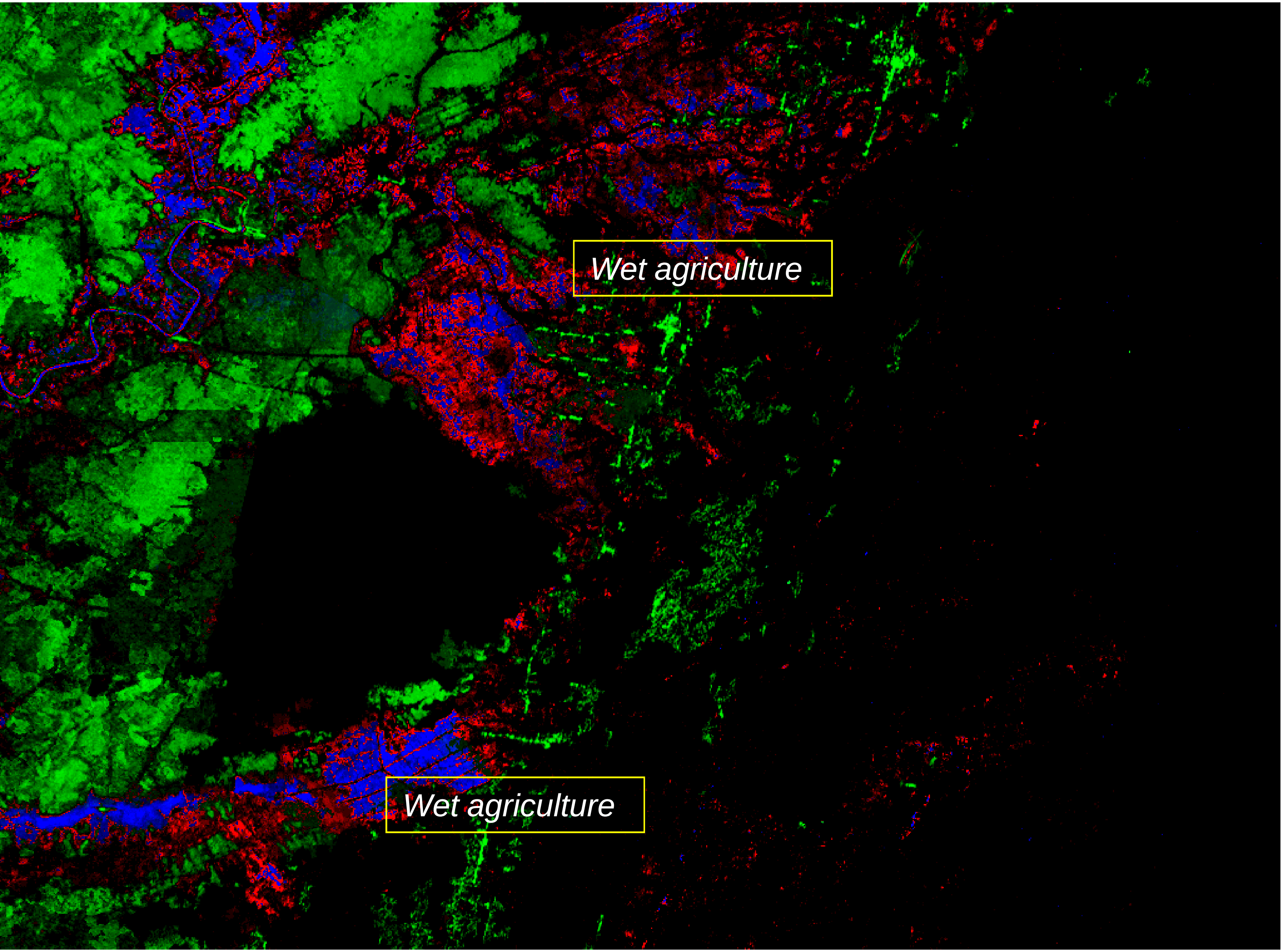
Mahakam delta

Cities can be mapped well with PALSAR data and are shown in red



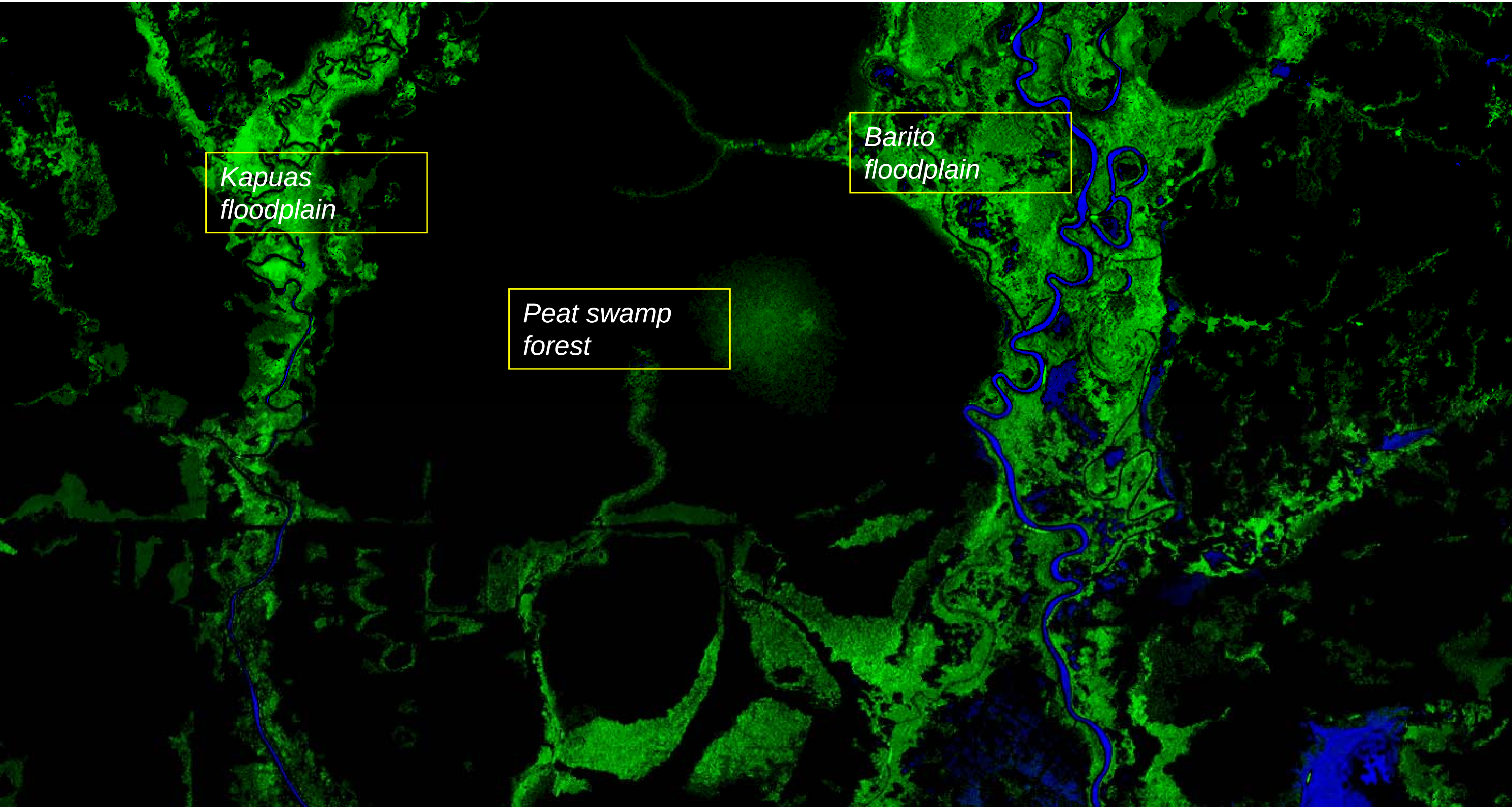
Bare soil frequency

Bare soils (in red) can be monitored as well

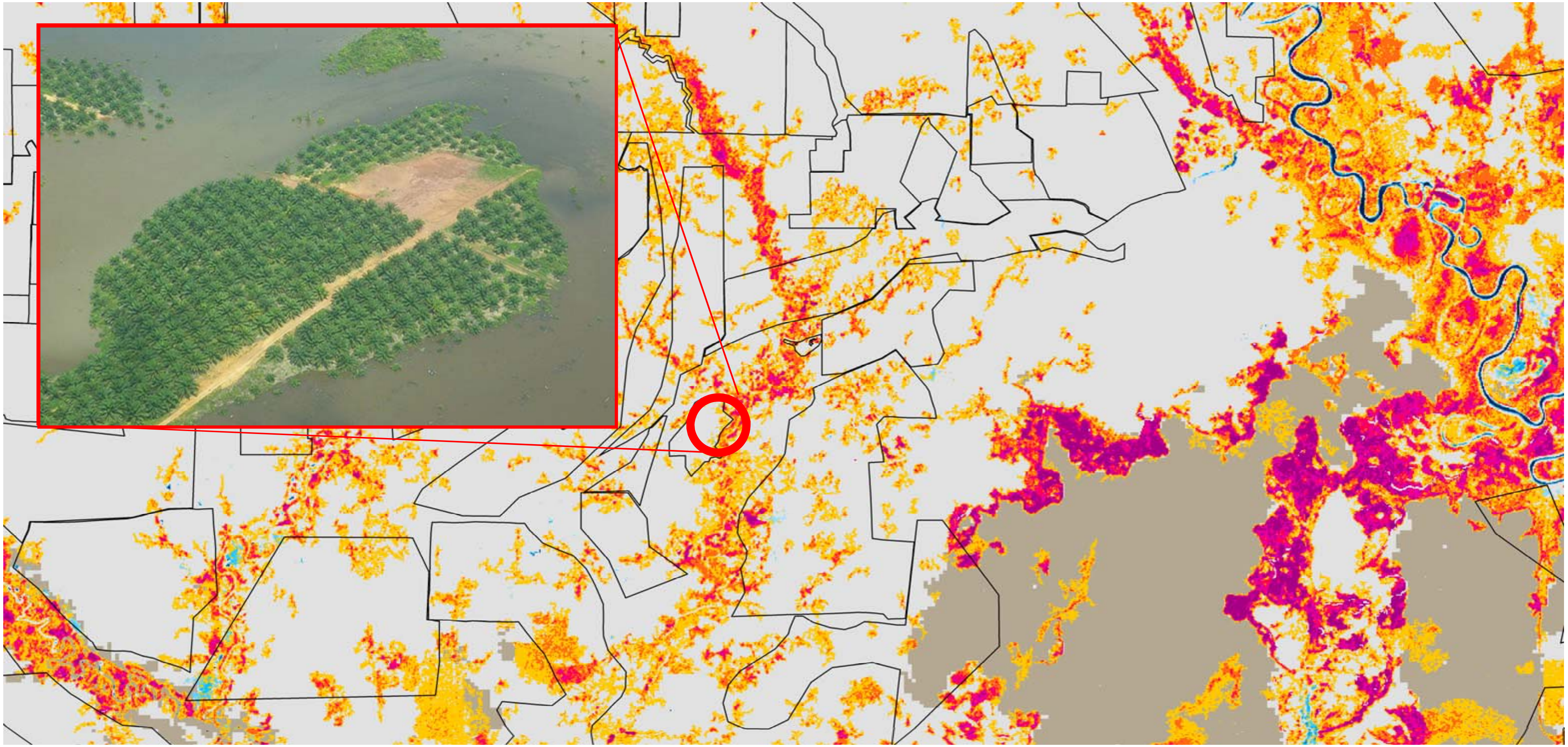


Wet agriculture near Banjarmasin

Though the system is not set up (nor calibrated) to map agriculture there is a large potential to map agricultural dynamics, especially for wet agriculture such as rice.

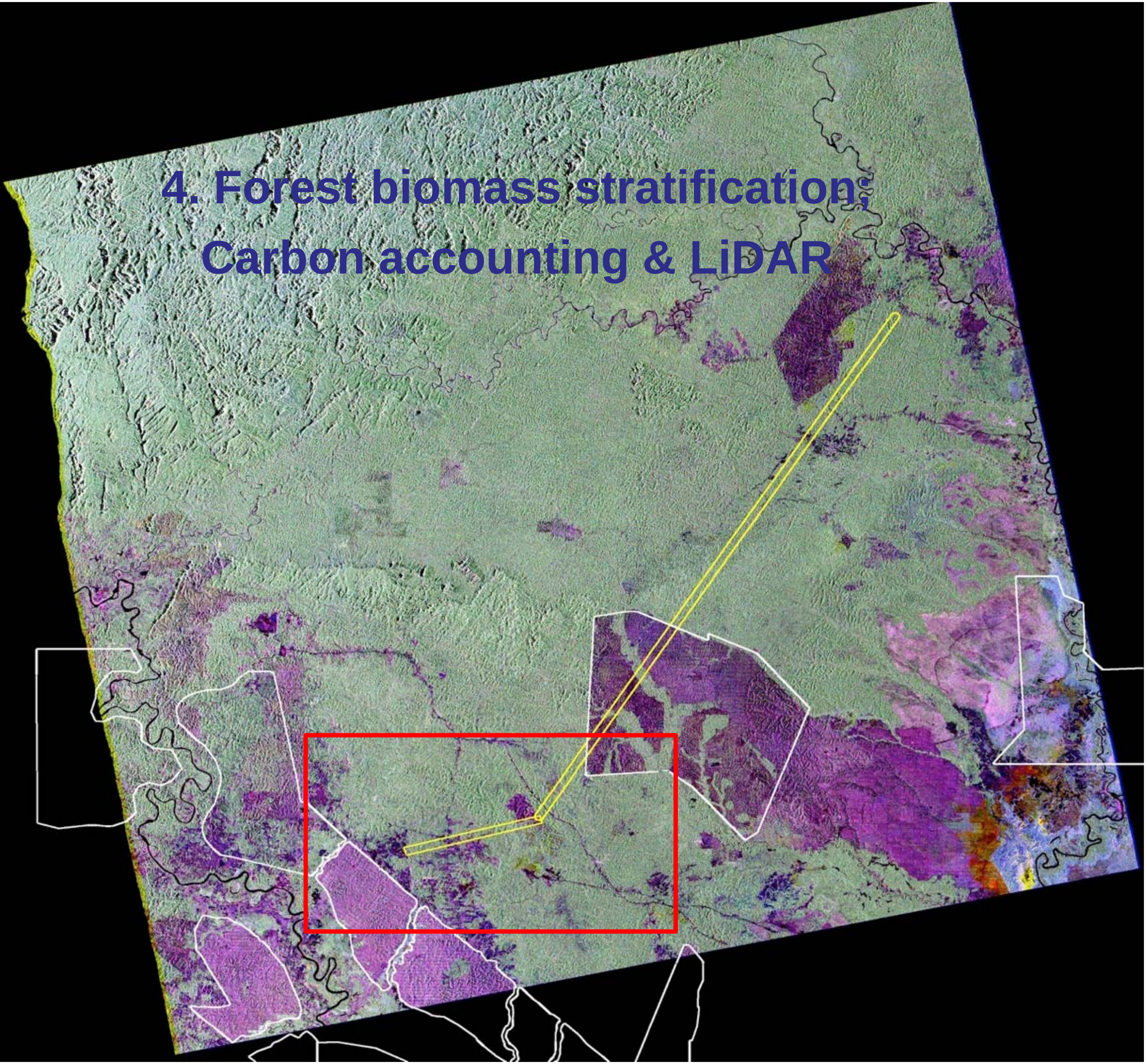


Barito and Kapuas river and floodplain
Area in between is mainly peat swamp forest



Aerial photography Dec 2011 confirms flooding in oil palm plantations

4. Forest biomass stratification; Carbon accounting & LiDAR

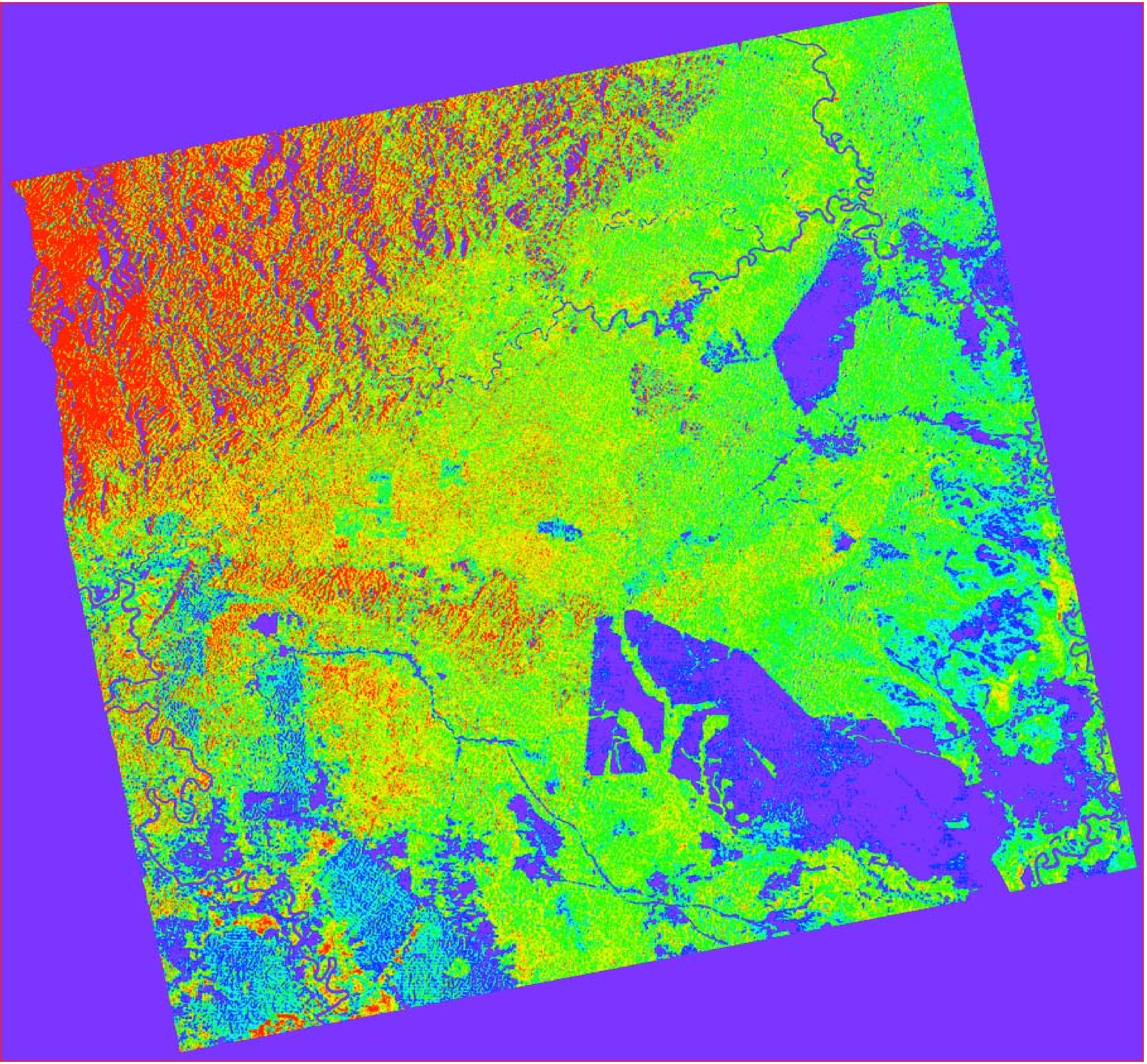


PALSAR-2 Fine Beam Standard image
- HH- and HV-polarisation
- 10m resolution
- ±70km x 70 km area

Dates of acquisition
- 20140915
- 20150202

LiDAR data
110,000 ha acquired at ±60 test sites in Kalimantan at the end of 2014 (yellow outline) Path 136 (lower yellow area) coincides with REA test site (red box).

REA area is outlined in white



PALSAR-2 Fine Beam Biomass proxy map

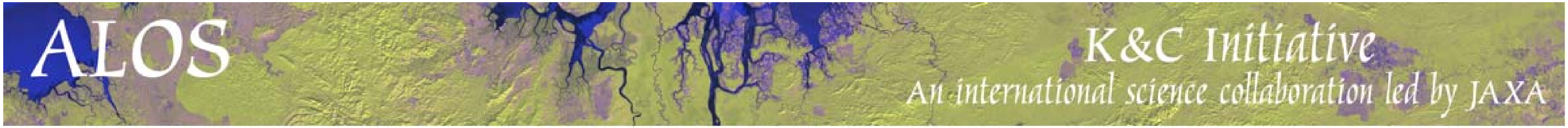
Map based on speckle-filtered, averaged (2 observation dates) and convoluted (1 ha MMU) image

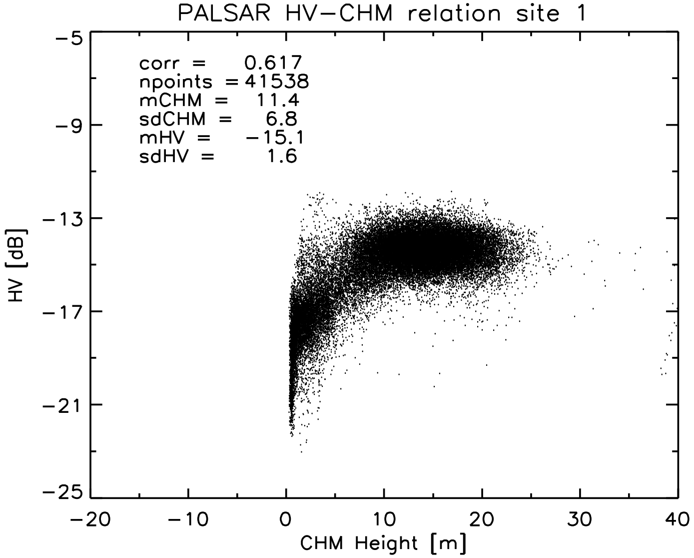
Full scene: 70kmx70km

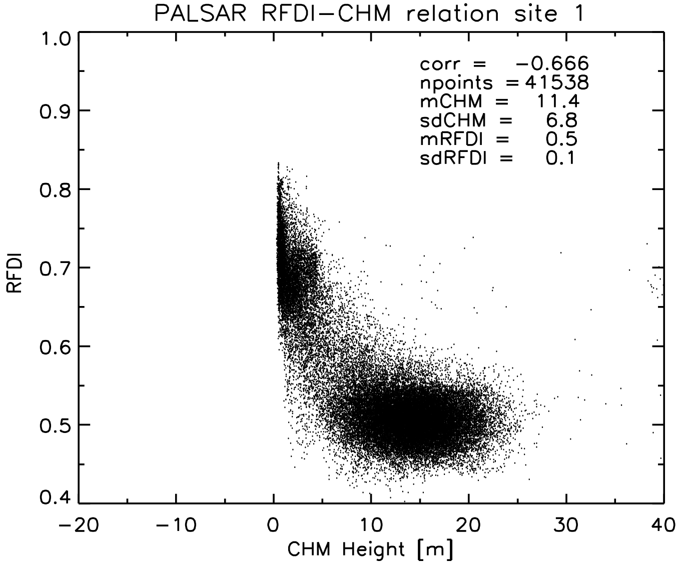
For final calibration-validation (LiDAR) vegetation height data as well as local plot-based biomass data are needed.

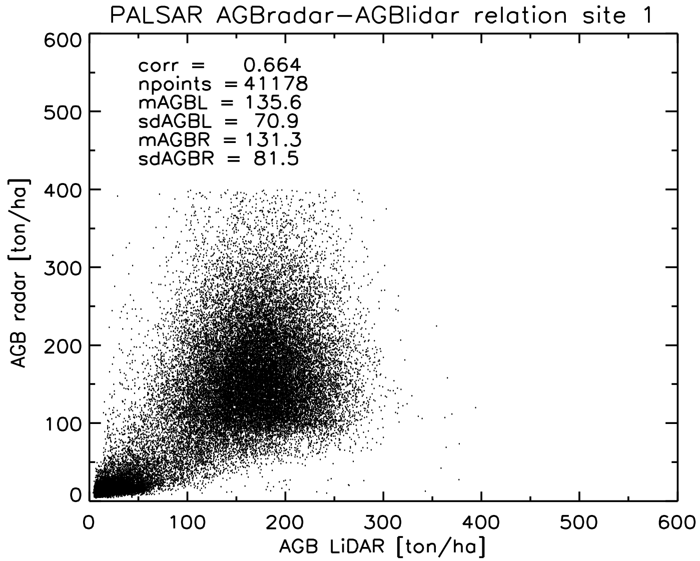
Since the latter is not yet available CHM-AGB allometry from literature is used.

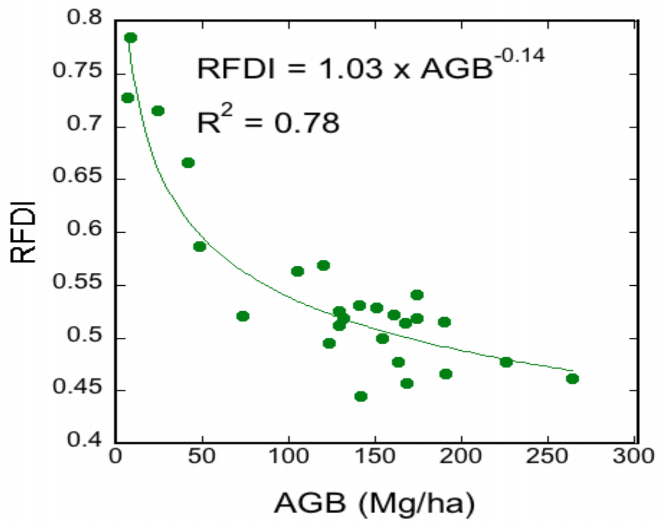
Legend:
Low-High = B-G-Y-R







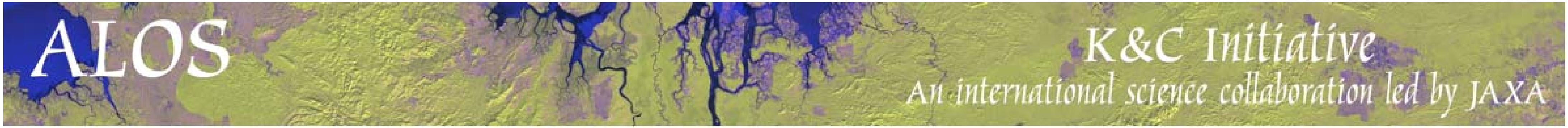


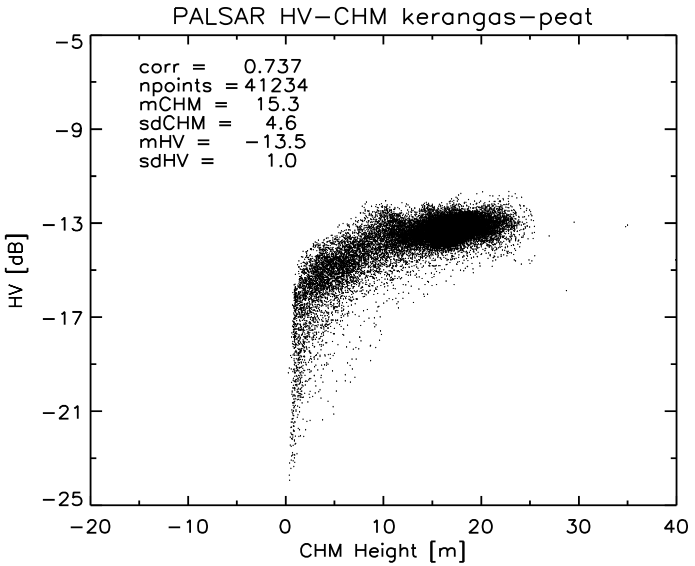


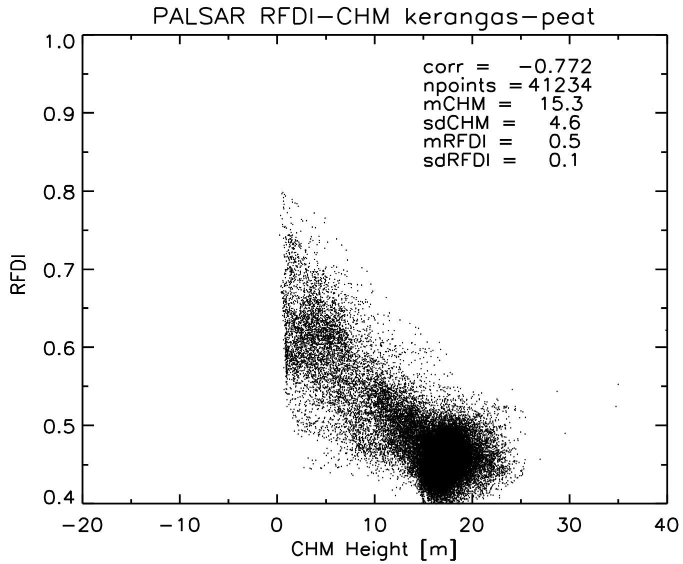
Secondary forest and plantations; LiDAR tracks 136 & 223

The radar-lidar relationships HV-CHM and RFDI-CHM behave ‘normal’. The latter is very similar to the RFDI-AGB relation (Saatchi et al., 2010). This relation, together with the CHM-AGB relation (Asner et al., 2014) is used to plot radar estimated AGB against LiDAR estimated AGB.

Note:
RFDI = (HH-HV)/(HH+HV)

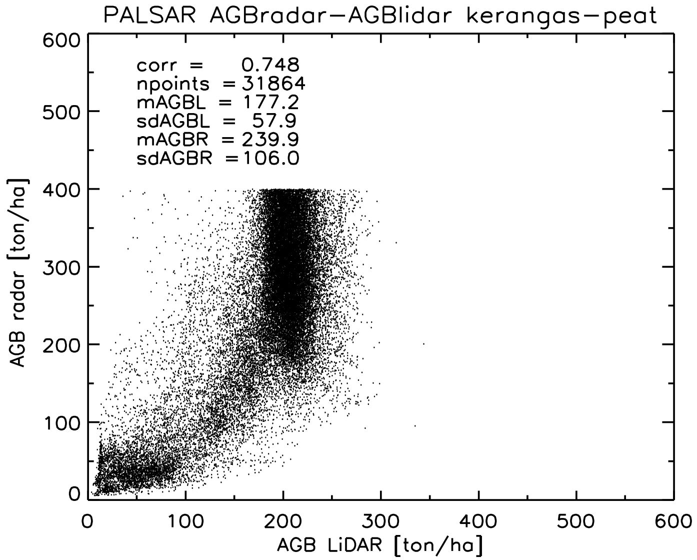


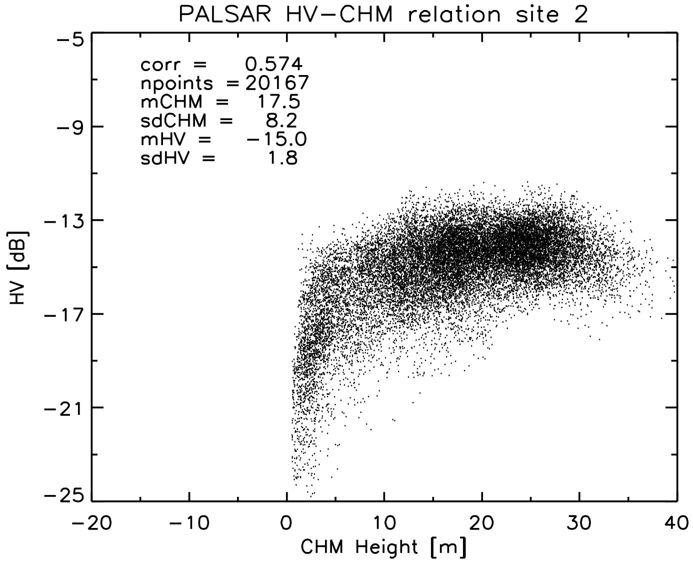


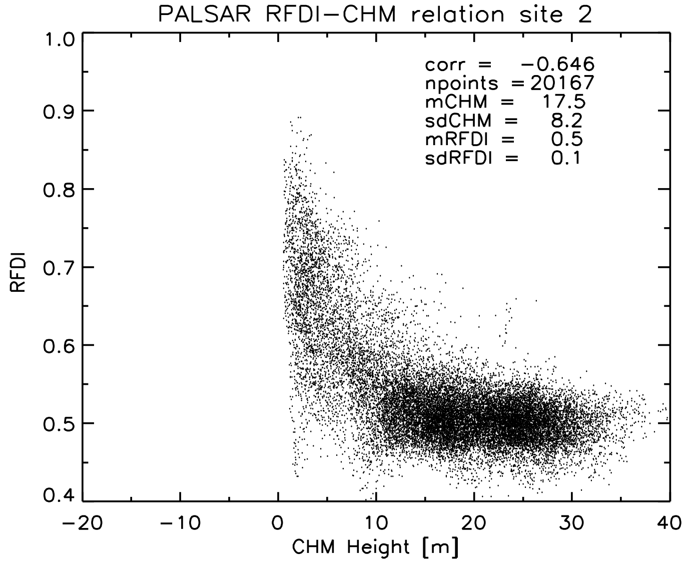


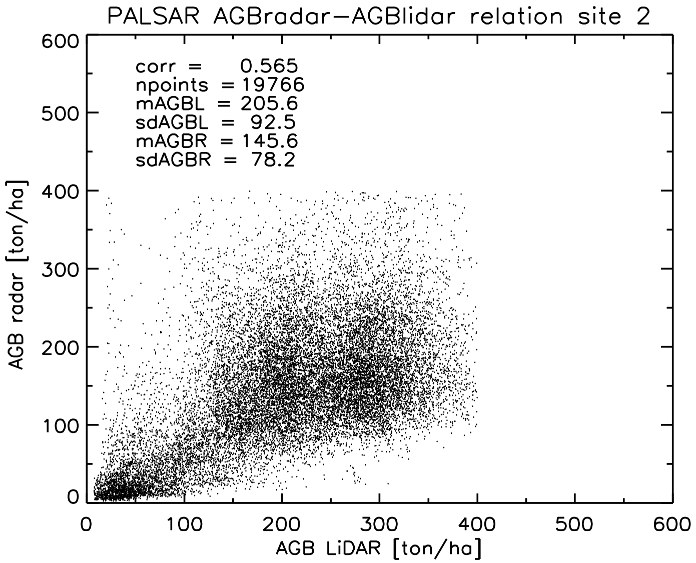
Kerangas and peat forest; flat areas; LiDAR tracks 13 & 243.

The peat forests exhibits an anomolous low RFDI resulting in a large overestimation of AGB.









Dipterocarp forest; short steep slopes; pristine and various degrees of degradation; LiDAR track 3 (a, b2 & c).

Here the relation is different. It seems AGB estimate based on radar compared to LiDAR is too low.

Remaining important issues

1.Multi-model slope correction needs to be done on PALSAR-2 path data

2.The effects of micro-relief (short steep hills) that cannot be corrected by SRTM DEM 1-arcsec data are prominent in many areas. RFDI mitigates this for dense vegetation, but not for sparse vegetation. For sparse vegetation micro-relief the RFDI is too high and biomass estimates too low. This can be mitigated with improved versions of the RFDI.

3.It seems relationships (allometry) depends on forest type. Therefore, forest type and land cover mapping and/or other types of stratification of Kalimantan is important.

4.Sentinel-1 (S1) has also been studied. Relationships between S1 radar and CHM are very weak (as expected). Nevertheless, Sentinel-1 can support stratification.

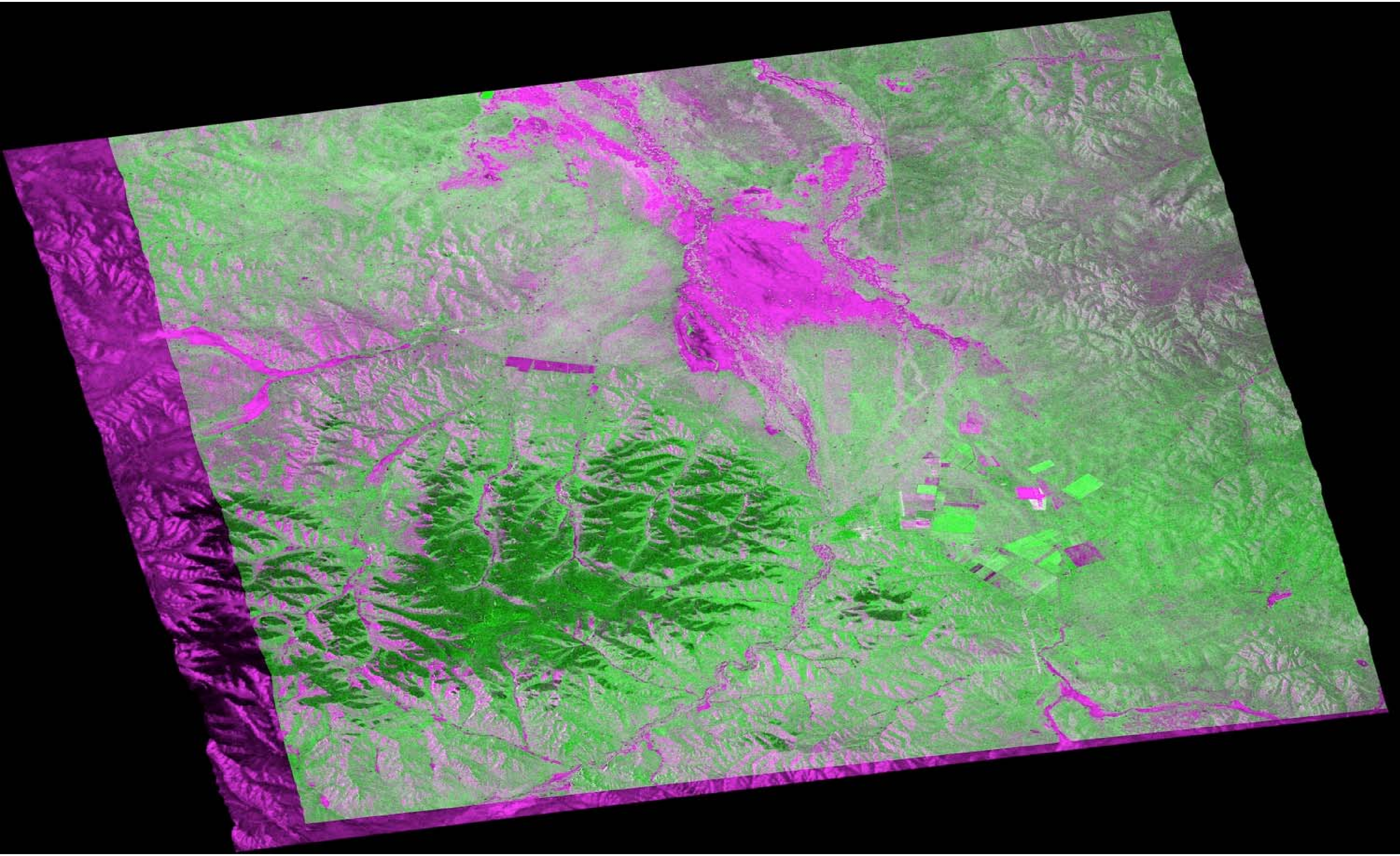
Mongolian study areas (non-K&C)

Mongolia is the only REDD+ country with boreal forest.

"The carbon emissions from Mongolia's peatlands are estimated at up to 45 million tons per year which makes Mongolia the seventh largest global emitter of CO_2 from degrading peatlands."

Mongolia considers use of PALSAR for environmental monitoring.

PALSAR-2 images show large contrasts between summer and winter (freezing conditions) for forests as well as peatlands.



Tuvshruuleh East area. Composite PALSAR-2 winter 20150120 – summer 20150924.
Forests show up in dark green; **wetlands** in magenta.

Project milestones & Data sharing

List the project milestones until March 2018 (the end of Phase 4)

Project milestones

A. Consistent time series of wide area land/forest cover maps for Borneo and Guiana Shield (2007-2010 & 2014-2017); Dec 2017 (path data required)

B. Decadal change maps ± 1997 – 2007 – 2017 (using JERS-1 mosaics and PALSAR-1); Dec 2017

C. Wetland dynamics maps of Borneo (periods 2007-2010 and 2014-2017); **Aug 2015 (Palsar-1)**; Dec 2017 (Palsar-2)

D. Multi-band wide area demonstration maps of Borneo (PALSAR-2 & Sentinel-1); **Mosaic Feb 2016**; LC June 2016

E. Forest and biomass stratification maps and deforestation hot spots maps for Borneo and Guiana Shield; **Multi-model slope Oct 2015; TSX Nov 2015**; Borneo Jun 2016; Guiana Shield Dec 2017

Deliverables etc.

Describe the planned output of your project.

- Project deliverables
- Other anticipated results

1. Consistent time series of wide area land/forest cover maps for Borneo and Guiana Shield (2007-2010 & 2014-2017)
2. Decadal change maps ± 1997 – 2007 – 2017 (using JERS-1 mosaics and PALSAR-1)
3. Wetland dynamics maps of Borneo (periods 2007-2010 and 2014-2017)

Deliverables etc.

Describe the planned output of your project.

- Project deliverables
- Other anticipated results

4. Multi-band wide area demonstration maps of Borneo (PALSAR-2 & Sentinel-1)
5. Forest and biomass stratification maps and deforestation hot spots maps for Borneo and Guiana Shield
6. Reporting methodological progress for (a) consistent time series, (b) multi-model slope correction, and (c) interoperability and complementarity (for PALSAR-2, Sentinel-1 and TerraSAR-X) at K&C meetings

Acknowledgement

This work has been undertaken within the framework of the JAXA Kyoto & Carbon Initiative. ALOS PALSAR data have been provided by JAXA EORC

Thank you