# K&C Phase 3

# Forest Cover Change and Biomass Mapping in Vietnam and Cameroon

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*Toulouse, France*

# Project Objective

To demonstrate the feasibility of forest information generated from ALOS-PALSAR to support Carbon Cycle Science and International Conventon (REDD) in two projects:

- Forest cover change and biomass mapping in Vietnam. Vietnam is a country where the planting trees programme is very active during the last decade.

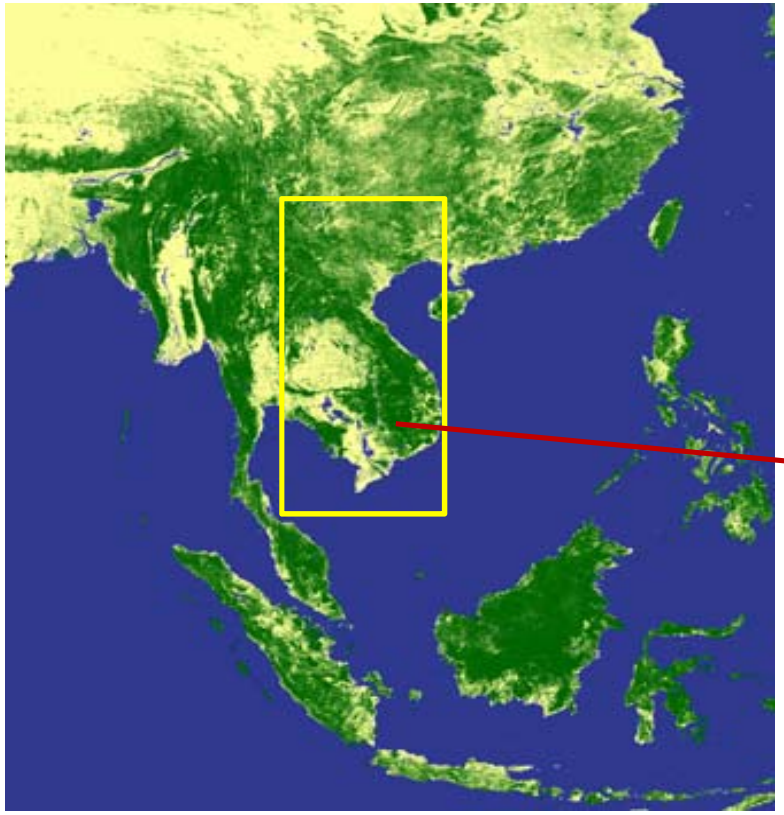
- Forest cover change and biomass mapping in Cameroon using ALOS PALSAR data, as a research part of the REDDAF project, also as a contribution to the GEO-FCT, Cameroon being one of the National Demonstrator.

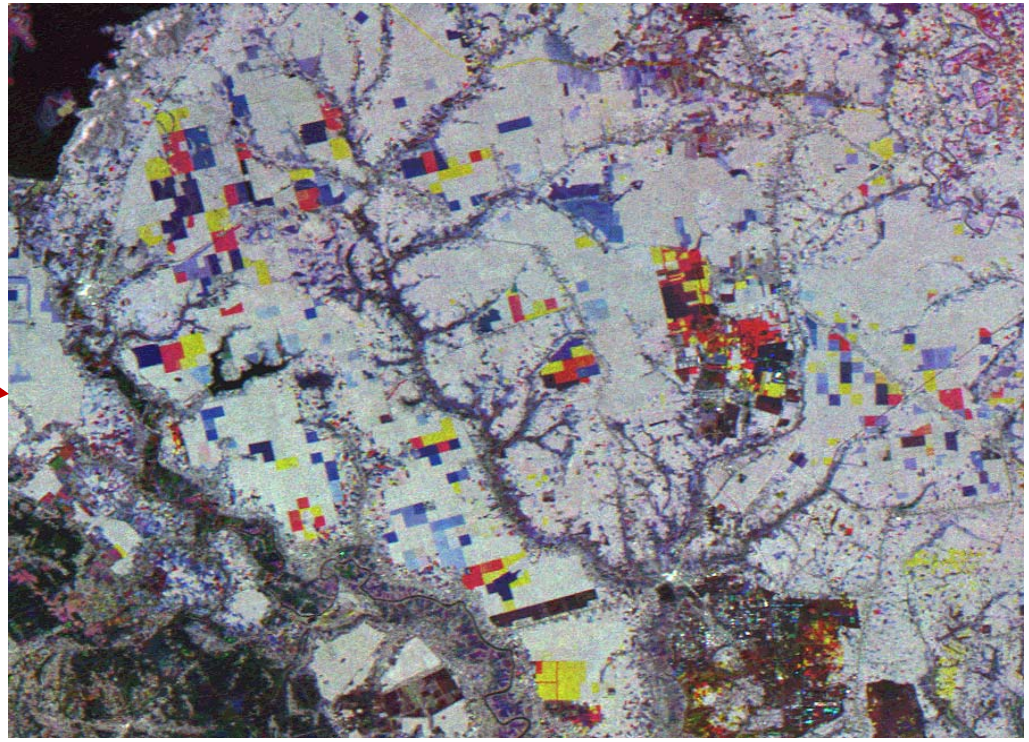
# VIETNAM: Reforestation and forest regrowth

- Vietnam: one of the most important rate of deforestation in the last 40 years and the most important rate of reforestation in the last 20 yrs

| FRA 2010 | 1990-2000 | 2000-2005 | 2005-2010 |
|---|---|---|---|
| Reduction of primary forest | 6.94% | 15.6% | 1.21% |
| Increase of planting trees | 7.8% | 6.4% | 4.7% |

- Planting trees
  - for agroforestry: rubber, coffee, fruit trees
  - for wood, fiber, fuel: acacia, eucalyptus .., with very fast turn over
  - for coastal environment (mangrove)
- Need to quantify removal and increase of carbon stocks, required in carbon calculations





*Red: forest cleared 2007-2008*
*Yellow: clearings between 2008-2009*
*Blue: young growing rubber*

*Multi-temporal PALSAR image over Dau Tieng, Vietnam (R: 2007; G: 2008; B: 2009). The area is part of the extensive rubber plantation programme*

Project Objective: Demonstration of the use of PALSAR data to measure carbon stocks and their changes associated to the de/af/reforestation programme

Method: Since the statistics in Vietnam are structured from local to national administrative units (district→province→ region→country), the test is done in prototype provinces

Expected results

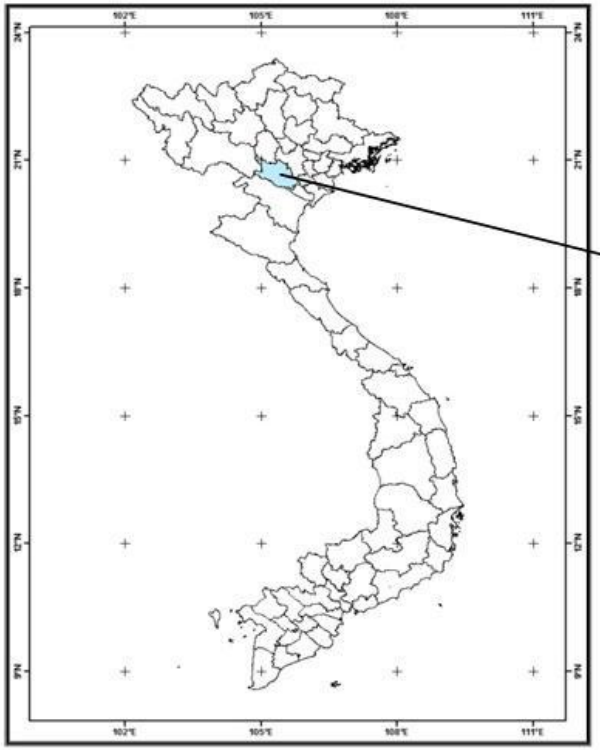
- ❑ Mapping in prototype provinces & country for 2007-2010 data
- ❑ Methodology developed for ALOS 2 data

# Collaboration in Vietnam

**Dr Tran Tuan Ngoc**
National Remote Sensing Centre,
Hanoi, Vietnam
**Prof. Pham Van Cu**
Vietnam National University, Hanoi.
Hanoi, Vietnam
**Dr. Lam Dao Nguyen**
GIS & Remote Sensing Research Center (GIRS)
HCMC Institute of Resources Geography (HCMIRG)
Vietnam Academy of Science and Technology (VAST)
Ho Chi Minh City, Vietnam

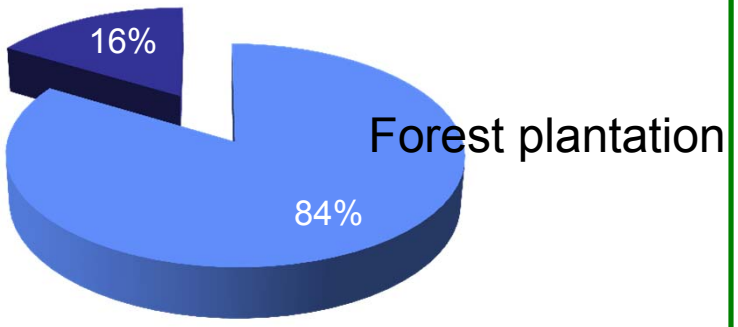
# Prototype province

The province of Thaibinh is selected for its active programme of tree plantation

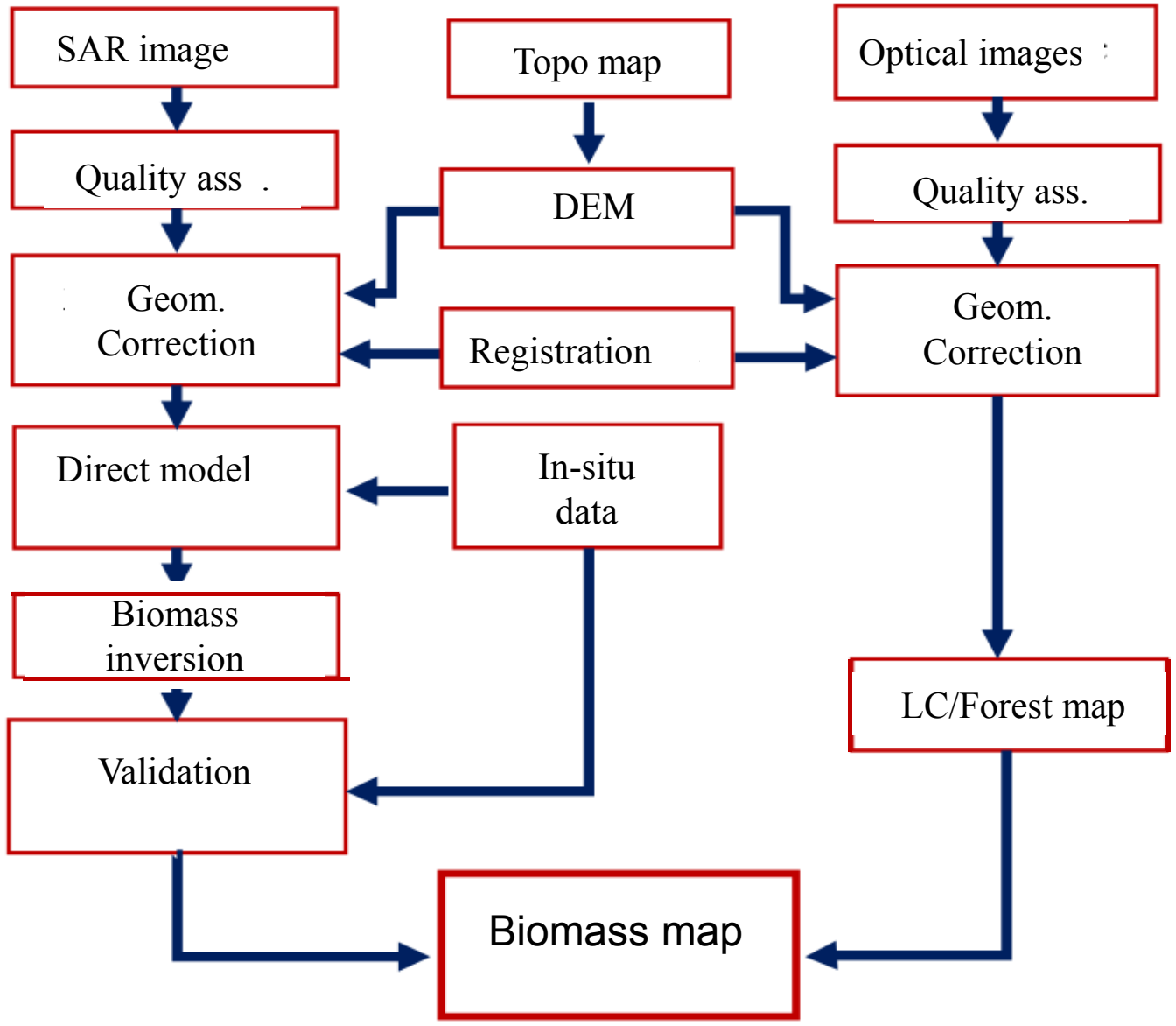



Total area: 469.912,2 ha,
Forest area: 208.922,1.

Natural forest

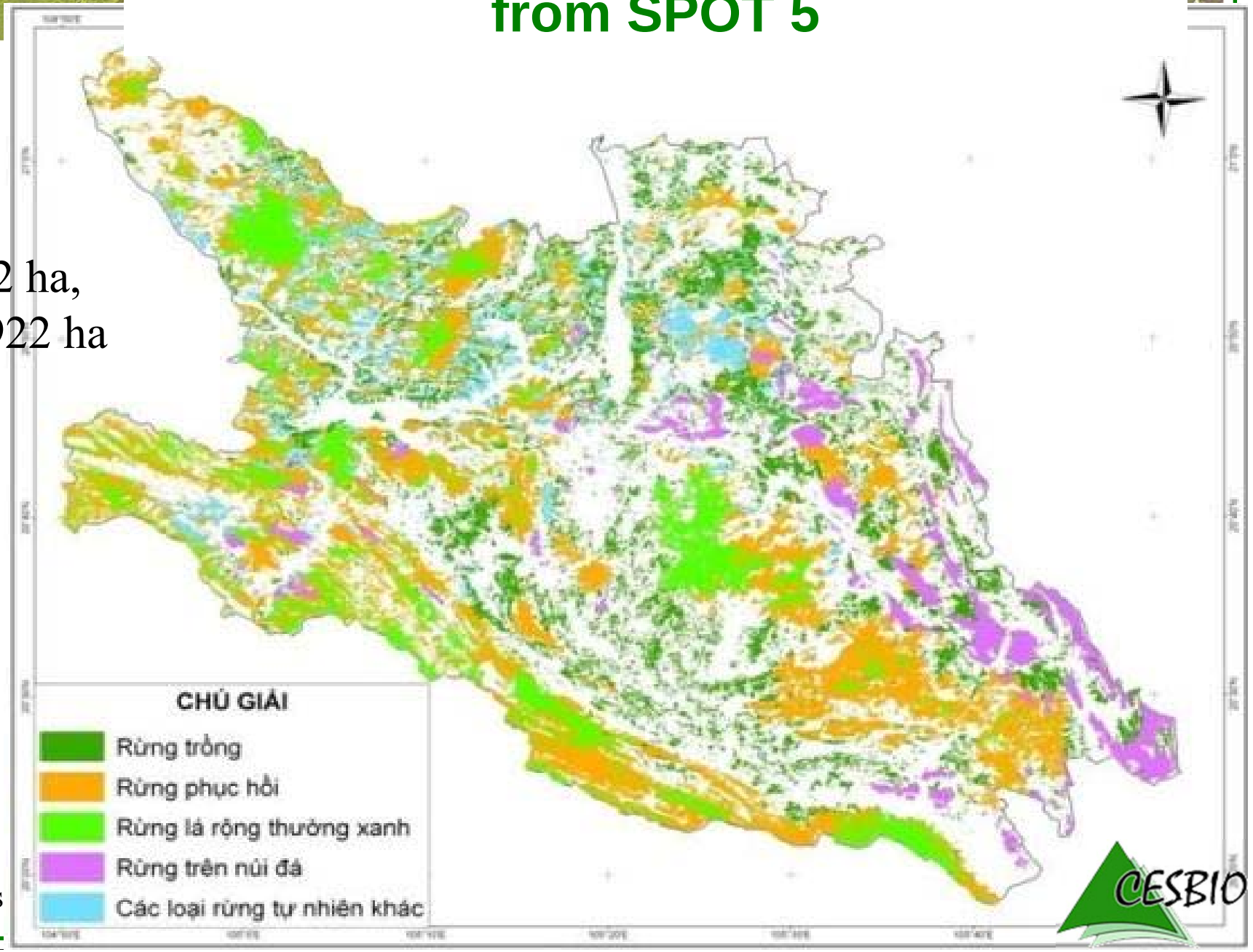


# Biomass mapping using ALOS-PALSAR implemented in Vietnam



# Forest and LC at Hoa Binh province from SPOT 5

Area: 469.912 ha,
Forest: 208.922 ha
( 55%)



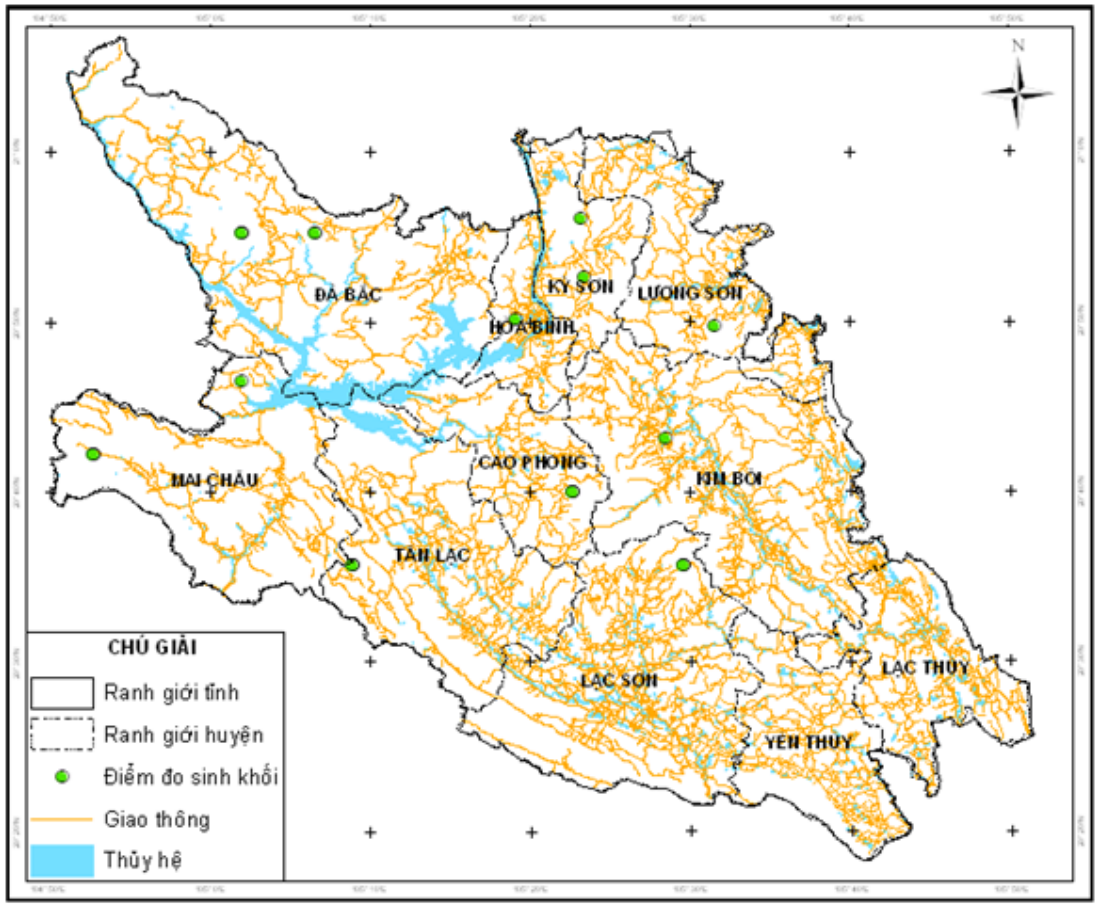

Plantation forest
Regenerating f.
Evergreen forest
Montane forest
Other natural forests

In situ data following IPCC guidelines with 20 x 20 m plots
More adapted to tree plantations, not to natural forest

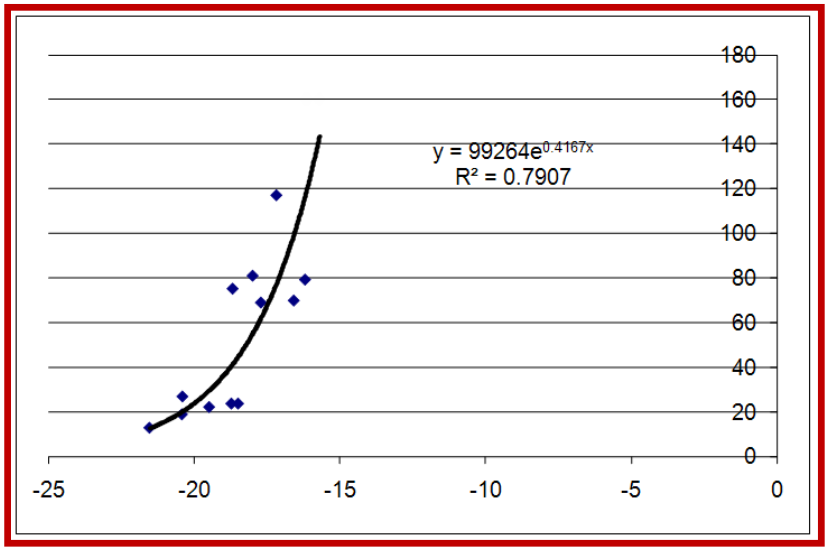
Natural forest

Plantation of *Acacia Mangium*

# In situ plots from forest inventory used to calibrate relationship between biomass-backscatter

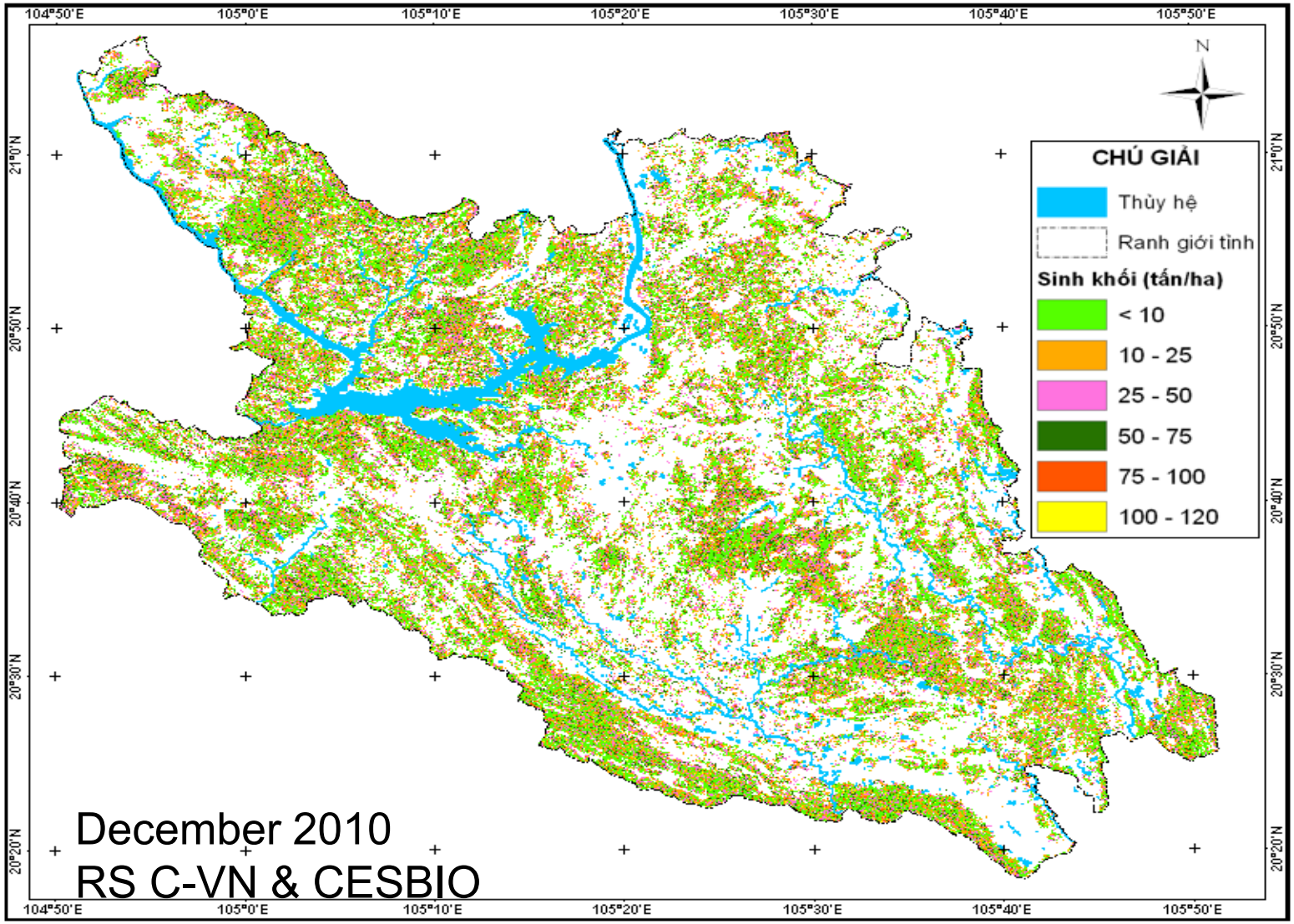



Biomass t/ha

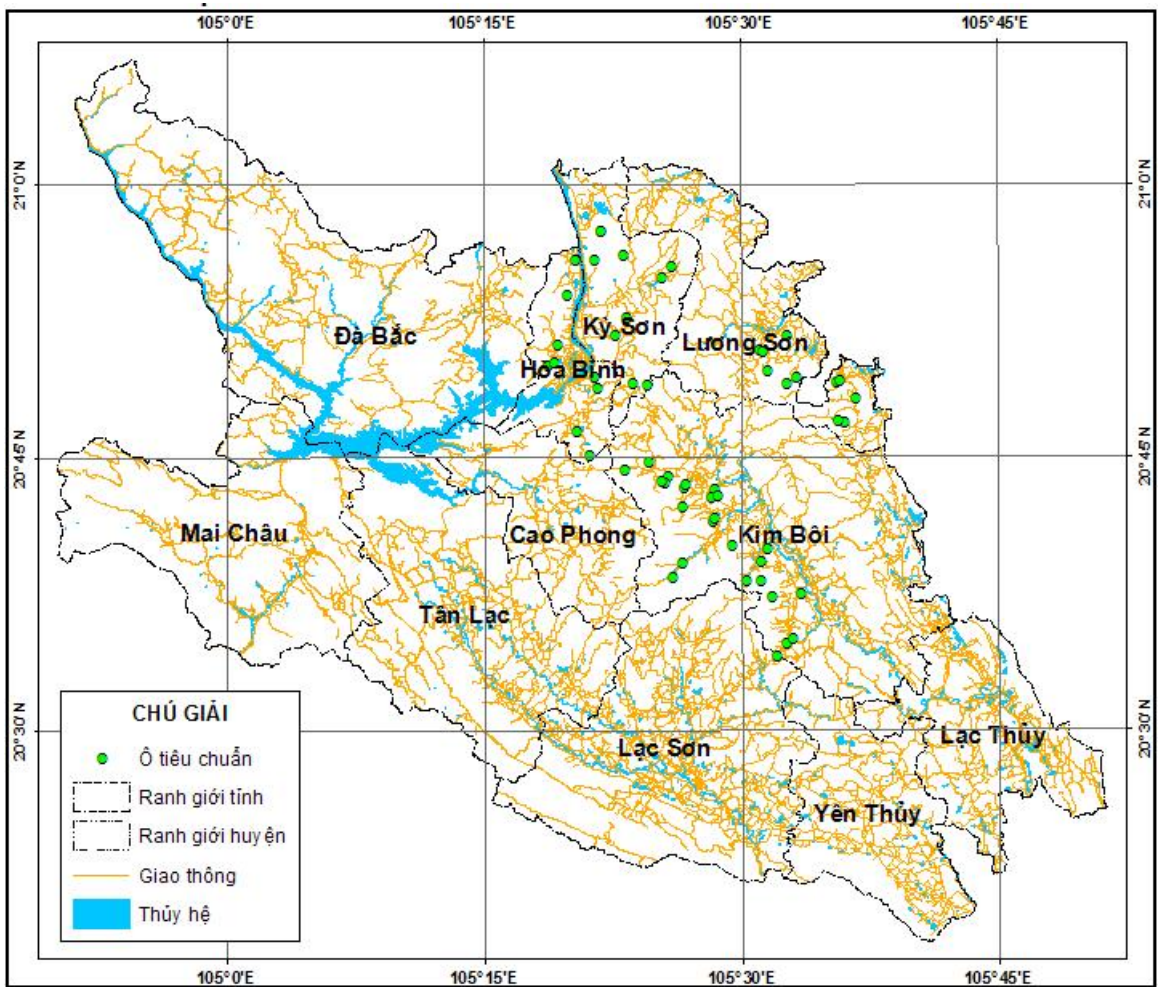


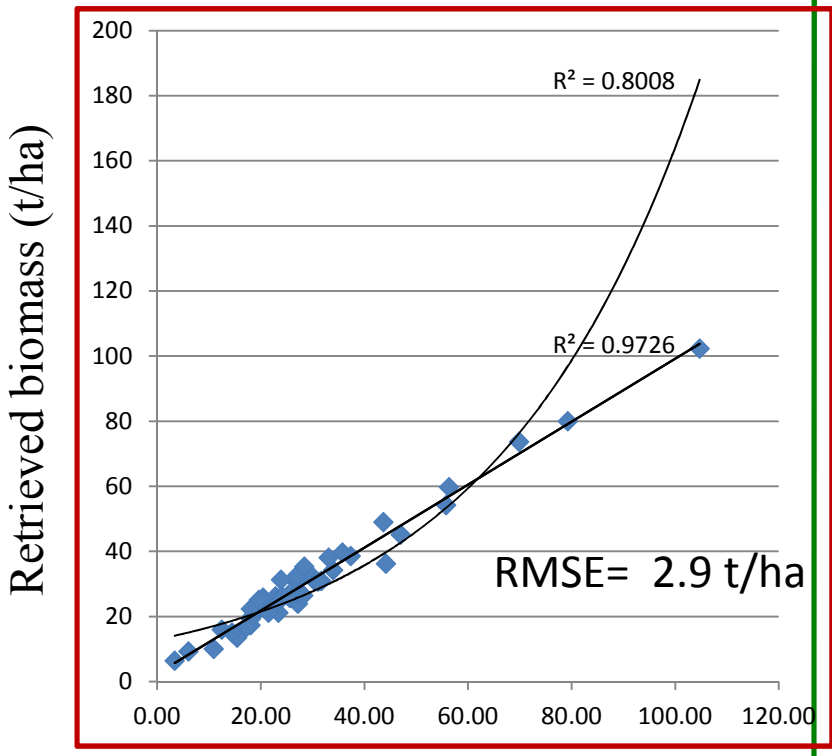

HV backscatter (dB)

# Forest biomass map using PALSAR data in Hoa Binh (2010)



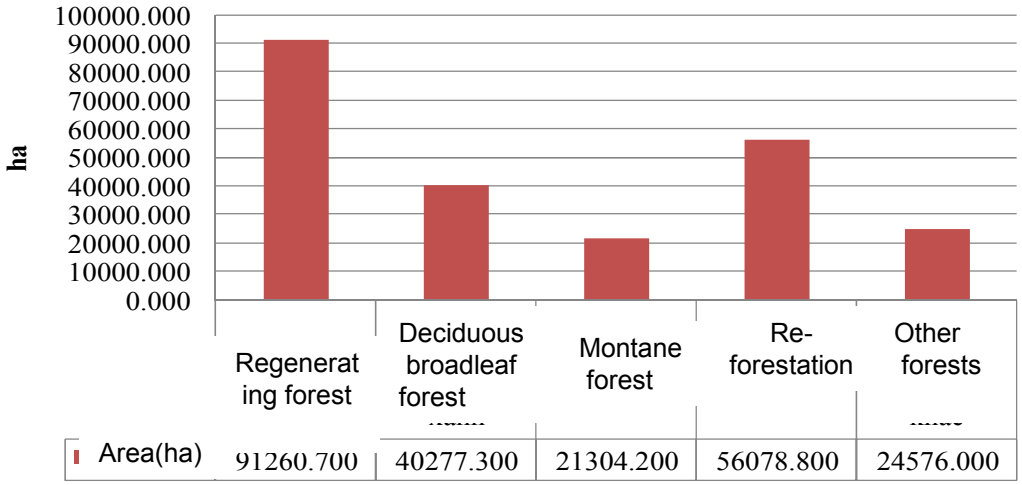
# Validation results



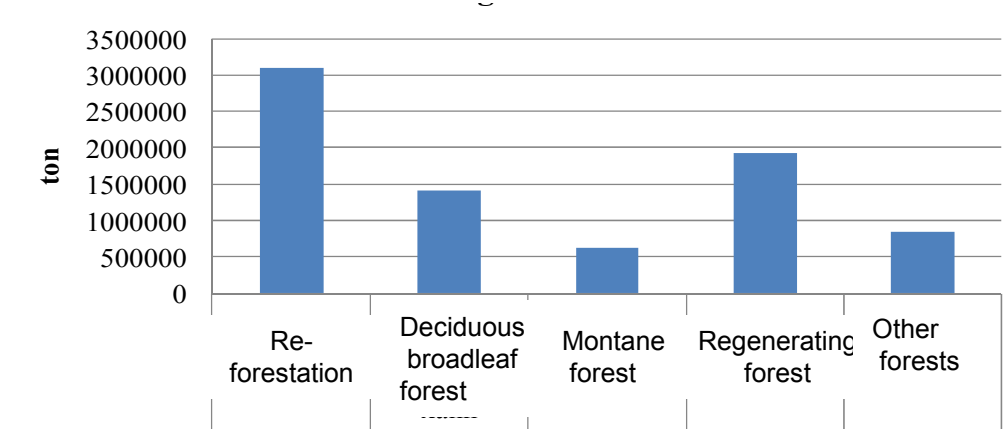
# Forest statistics to be used for the Hoa Binh province

## Area of forest classes in the province of Hoa Binh



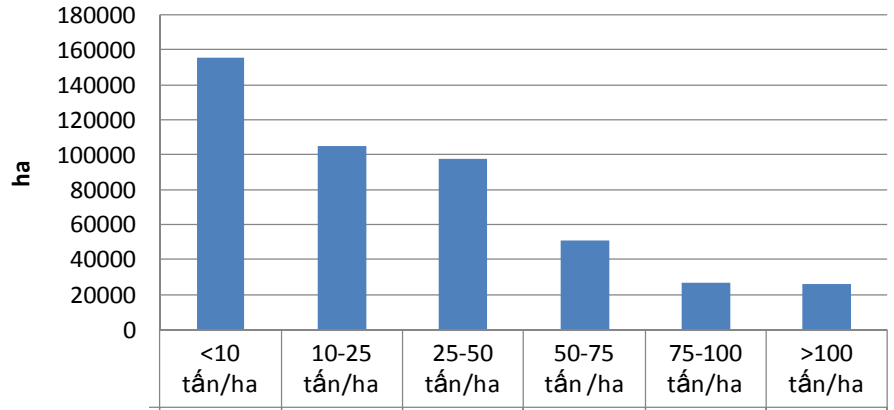

| | Regenerating forest | Deciduous broadleaf forest | Montane forest | Re-forestation | Other forests |
|---|---|---|---|---|---|
| Area(ha) | 91260.700 | 40277.300 | 21304.200 | 56078.800 | 24576.000 |

## Distribution of biomass in the province of Hoa Binh




| | Re-forestation | Deciduous broadleaf forest | Montane forest | Regenerating forest | Other forests |
|---|---|---|---|---|---|
| Biomass (tons) | 3103625 | 1415572.5 | 616847.5 | 1917085 | 851367.5 |

## Statistics of biomass, province of Hoa Binh




| | <10 tấn/ha | 10-25 tấn/ha | 25-50 tấn/ha | 50-75 tấn /ha | 75-100 tấn/ha | >100 tấn/ha |
|---|---|---|---|---|---|---|
| Area (ha) | 155831.5 | 105196 | 97761.75 | 51018.5 | 27011.25 | 25871.5 |

# Deliverables: Vietnam

- Forest biomass for prototype provinces (31.04.2012)
- Forest cover and cover change for Vietnam (31.03.2013)
- Forest biomass for all prototype provinces (31.03.2013)
- Forest biomass for Vietnam (31.03.2014)

# Cameroon

**CESBIO participates to:**

- **1) the REDDAF project (REDD in Africa),**

  Coordinator: GAF, Germany, Partners: Mesa-Consult, Germany, SIRS, France, CESBIO, France, Joanneum Research, Austria, and Geospatial Technology Group, Cameroon)

**2) GEO-FCT project for Cameroon, which is National Demonstrator**

**CESBIO objective:**

**Biomass assessment using Remote Sensing data (mainly PALSAR)**

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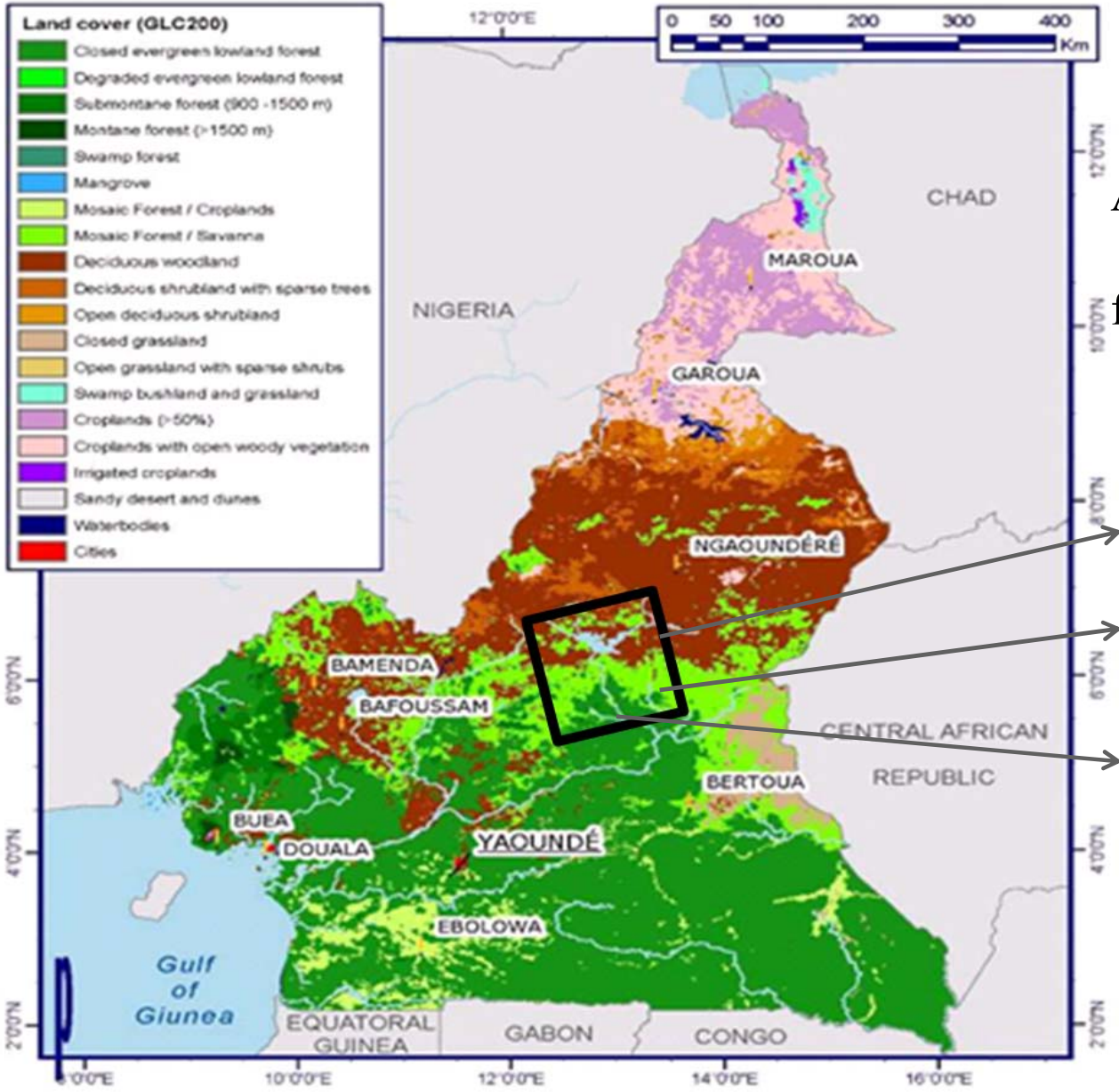
# REDDAF Study site 3: Direct EO biomass assessment



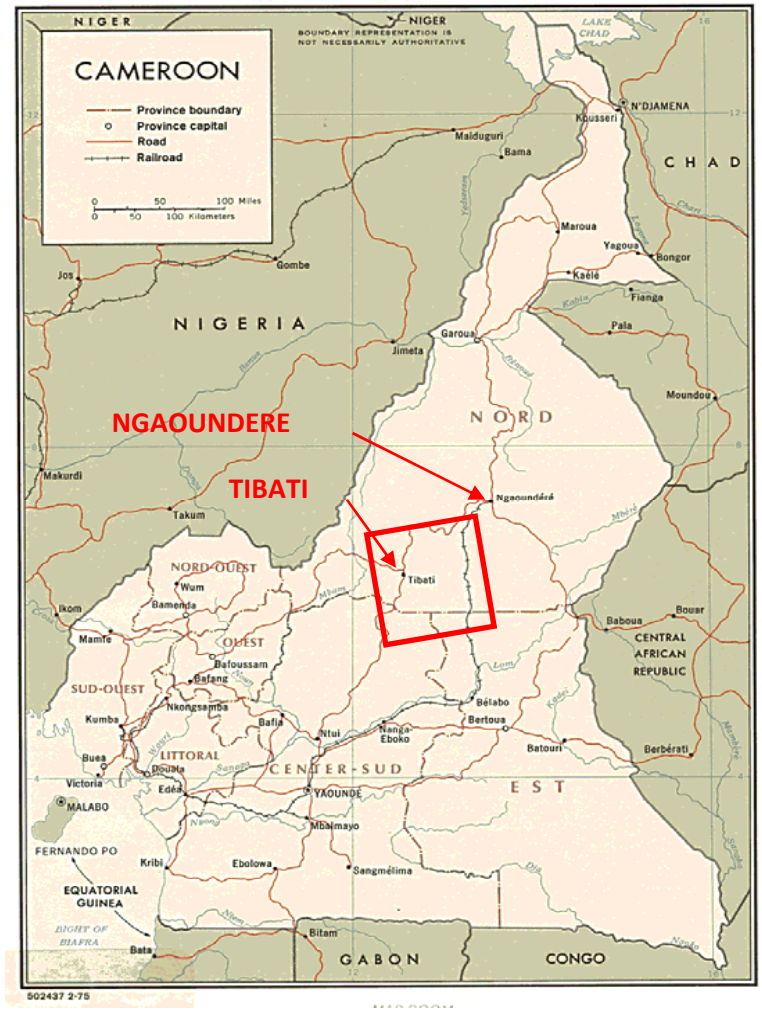

Adamawa test area:
interface between humid forest and savanna

**Deciduous schrubland with sparse trees**

**Mosaic of forest-savanna**

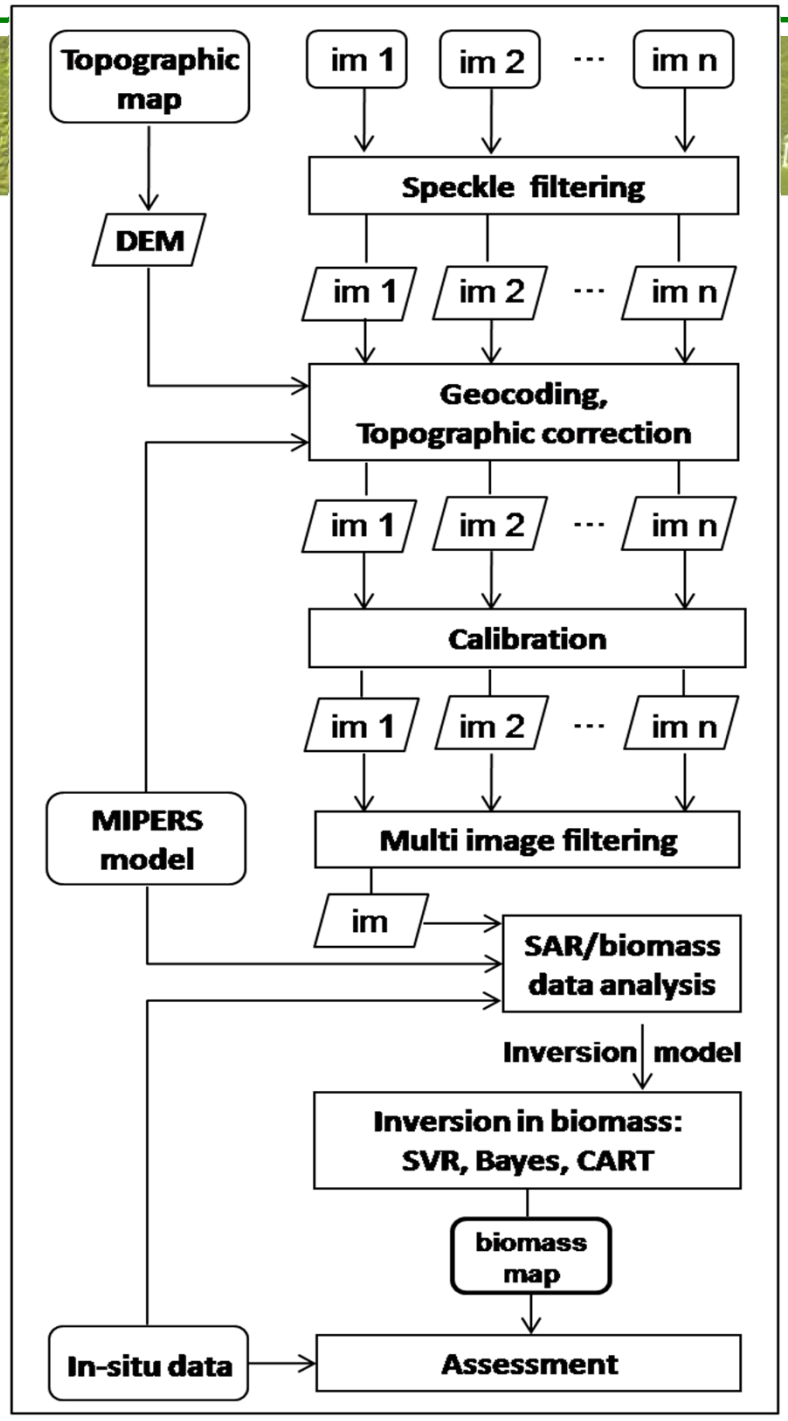
**Evergreen low land forest**

# Cameroon Forest-savanna ecosystem




- An important ecosystem in Cameroon:
  - →5.9 M ha forest-savanna mosaic
  - →4.5 M ha forest-agriculture mosaic
- No carbon inventory (Cerruti et al., 2008)
- Prone to lost of carbon at forest edges in populated rural area
- Potential of SAR data to estimate biomass and to detect changes

→ Motivation for demonstration study on biomass mapping and biomass change detection using ALOS-PALSAR of 2007 to 2010.




# Data processing flowchart

- Includes research components
- to be simplified after testing/validation
- based on in-house and free software for wider implementation

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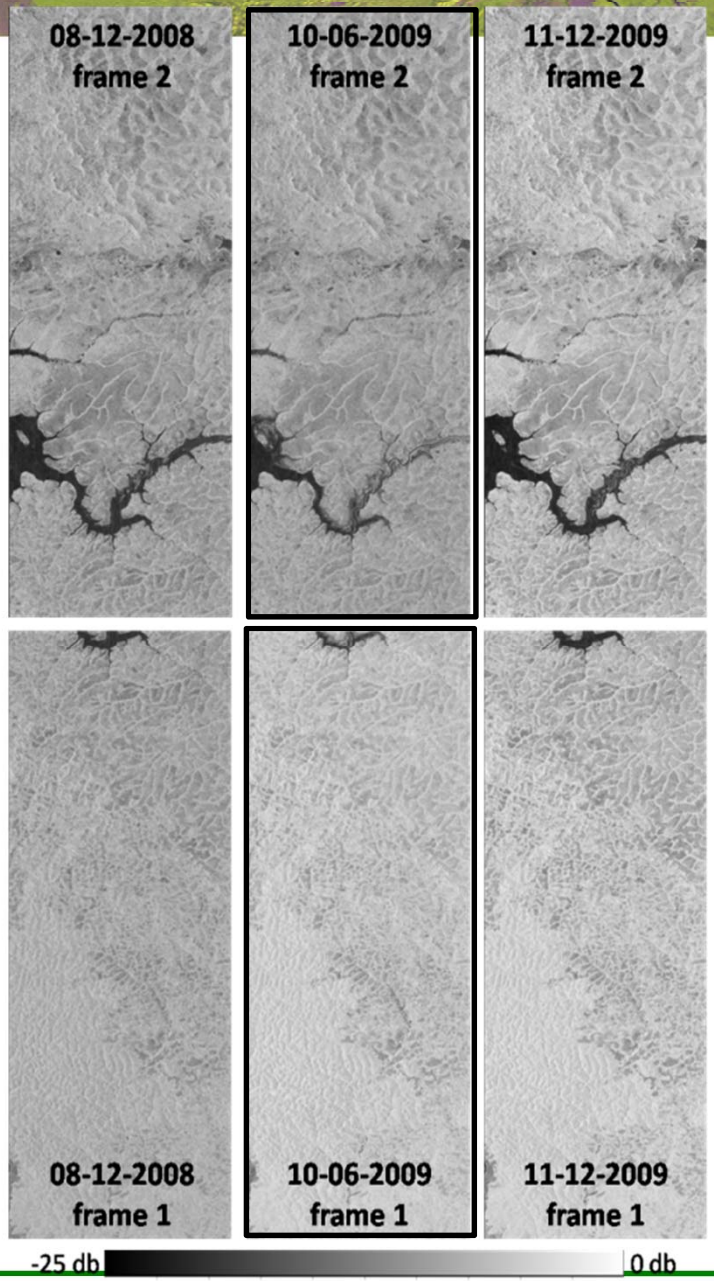
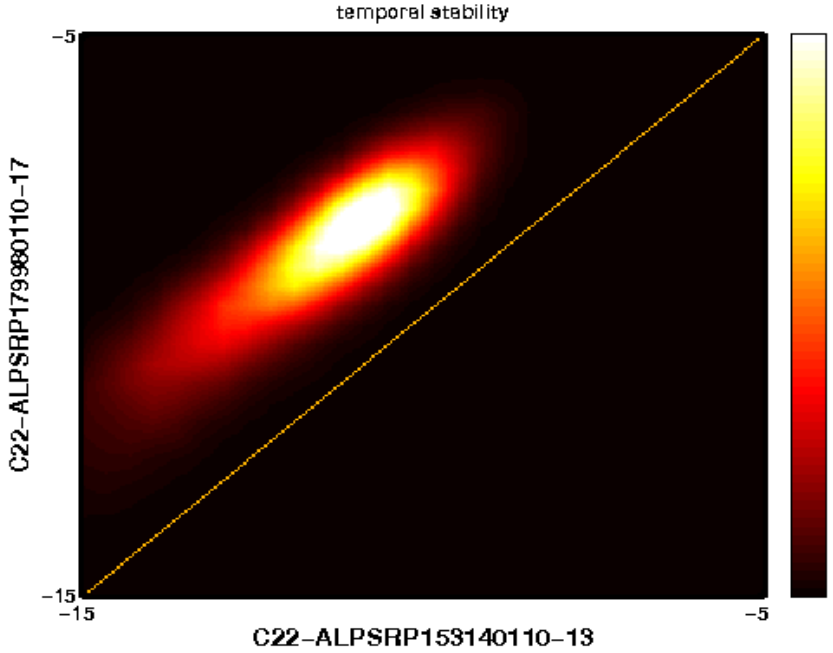
# Processing chain adaptation




Shift of ≈ 3db

→ radiometric calibration needed



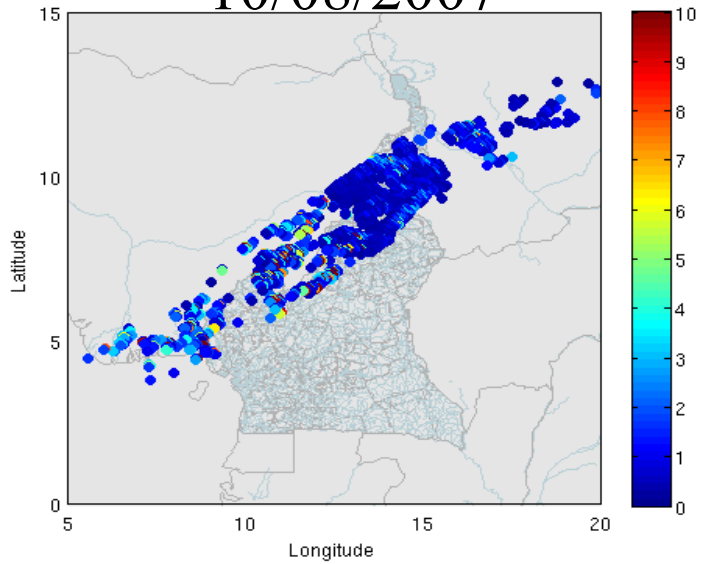

Calibration developed:

$$|S_{XY}|^2_{i,corrected} = a_i \cdot |S_{XY}|^2_i + b_i$$

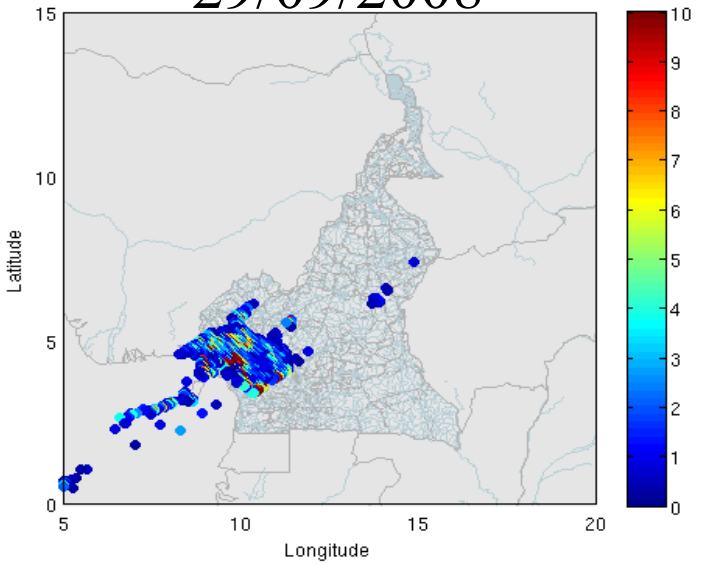
$$i = \{1, \ldots, n\} \qquad \{a_i, b_i\} \in \mathbb{R}^2$$

# Tropical Rainfall Measuring Mission (TRMM) data

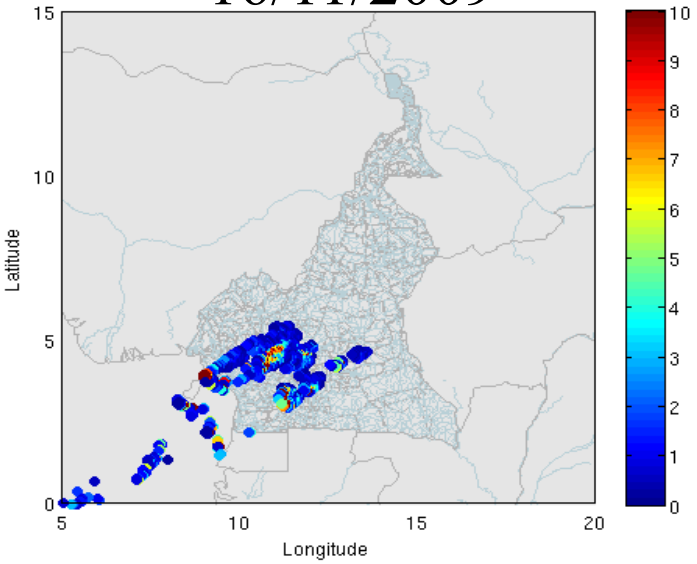
10/08/2007



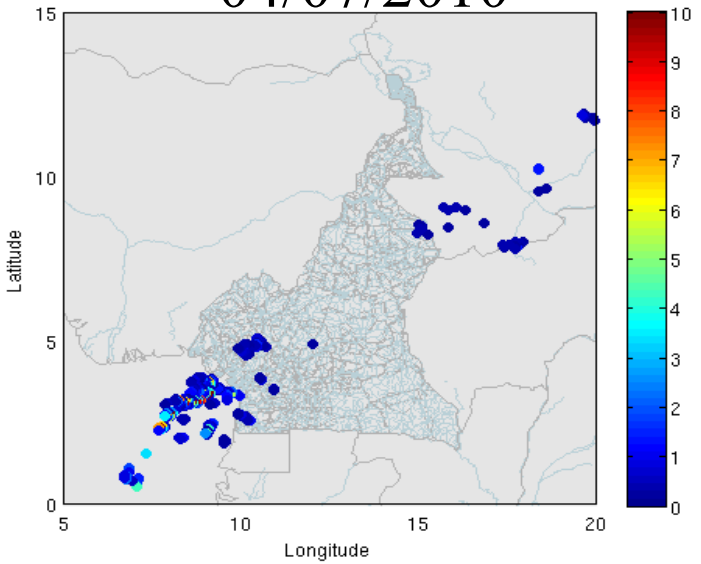

29/09/2008




16/11/2009




04/07/2010

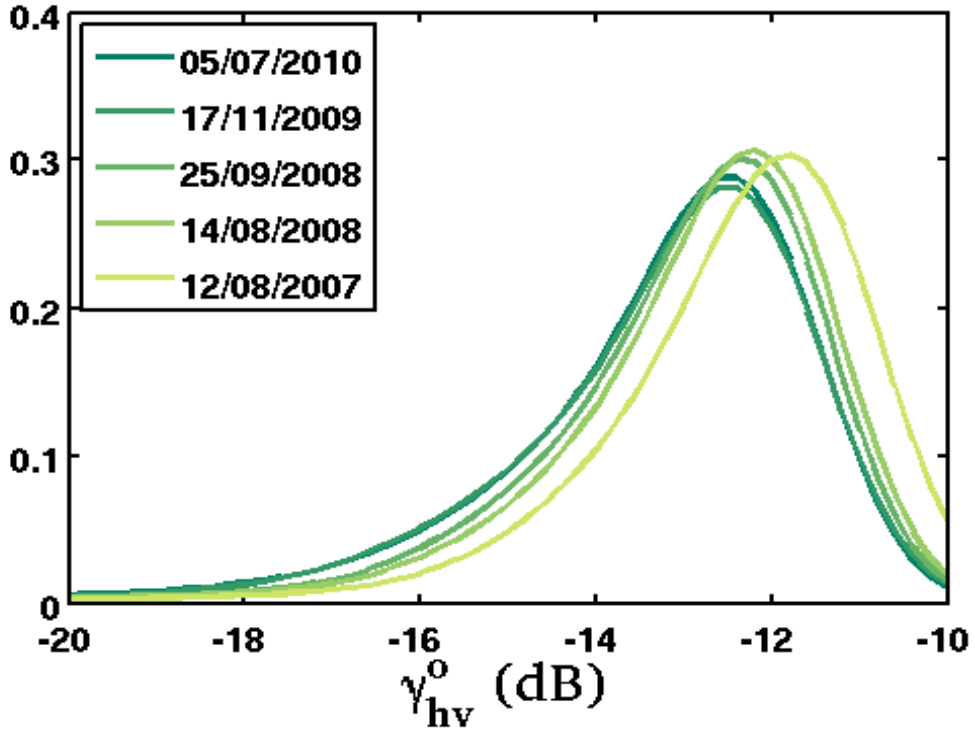


# Calibration

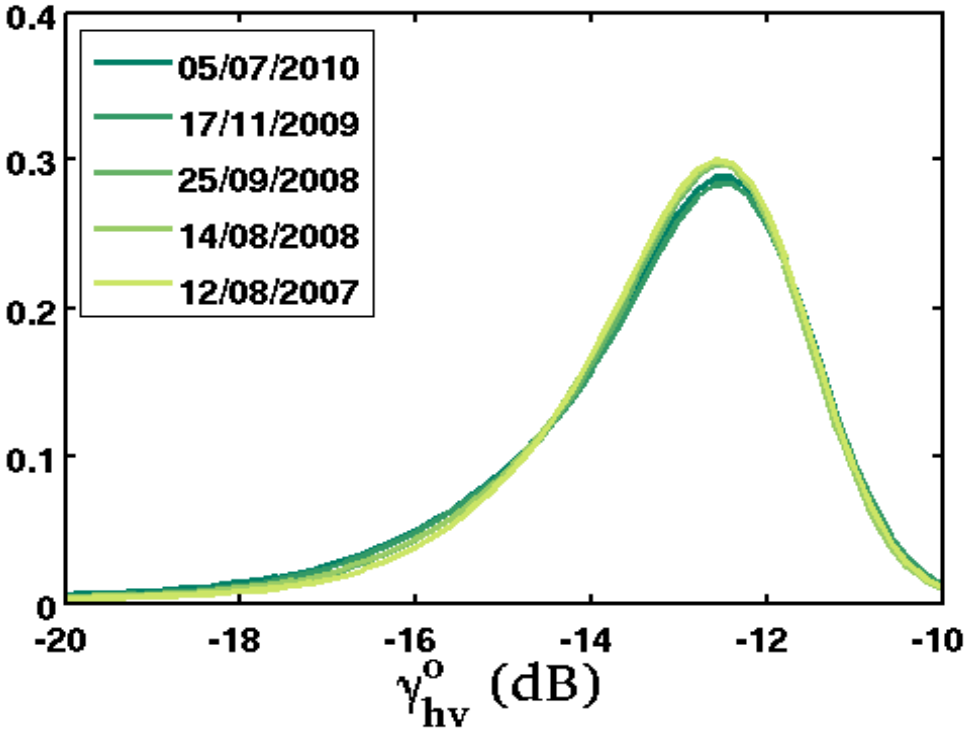
- Regression using Principal component analysis (PCA)
- Selection of the stable points (criteria: $r^2>0.9$)
- Pair 1-2: $G_{1-2} = \sigma_2/\sigma_1$ and $O_{1-2} = \mu_1-\mu_2.(\sigma_2/\sigma_1)$ with $\sigma$ the std and $\mu$ the mean
  Pair n-n+1: $G_{n-n+1} = \sigma_n/\sigma_{n+1}$. $G_{n-1-n} \dots G_{1-2}$ and $O_{n-n+1} = \mu_n+\dots \mu_1 -[\mu_{n+1}.G_{n-1-n} \dots G_{1-2} (\sigma_2/\sigma_1)]$

Stop criteria

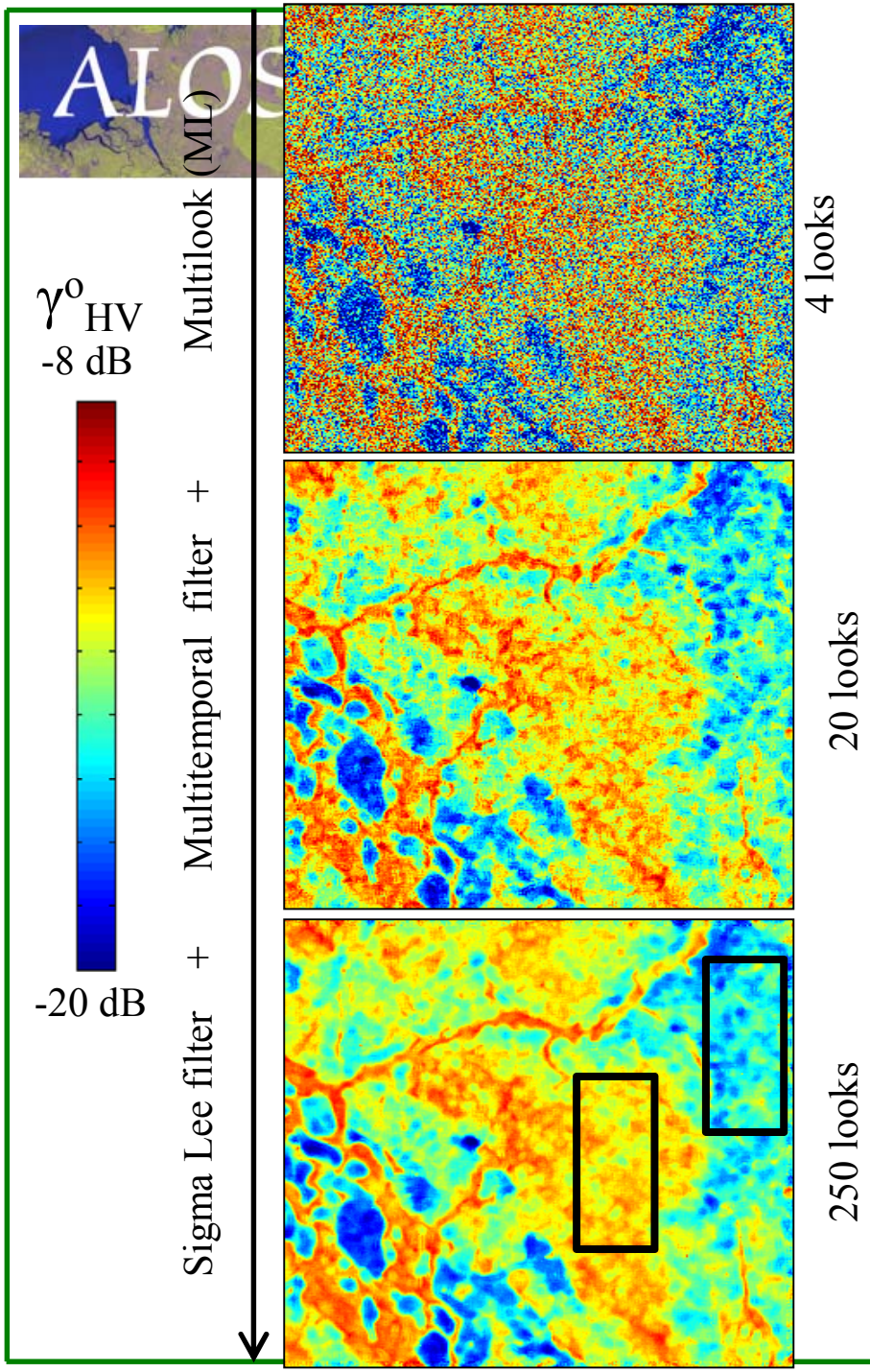
Before calibration

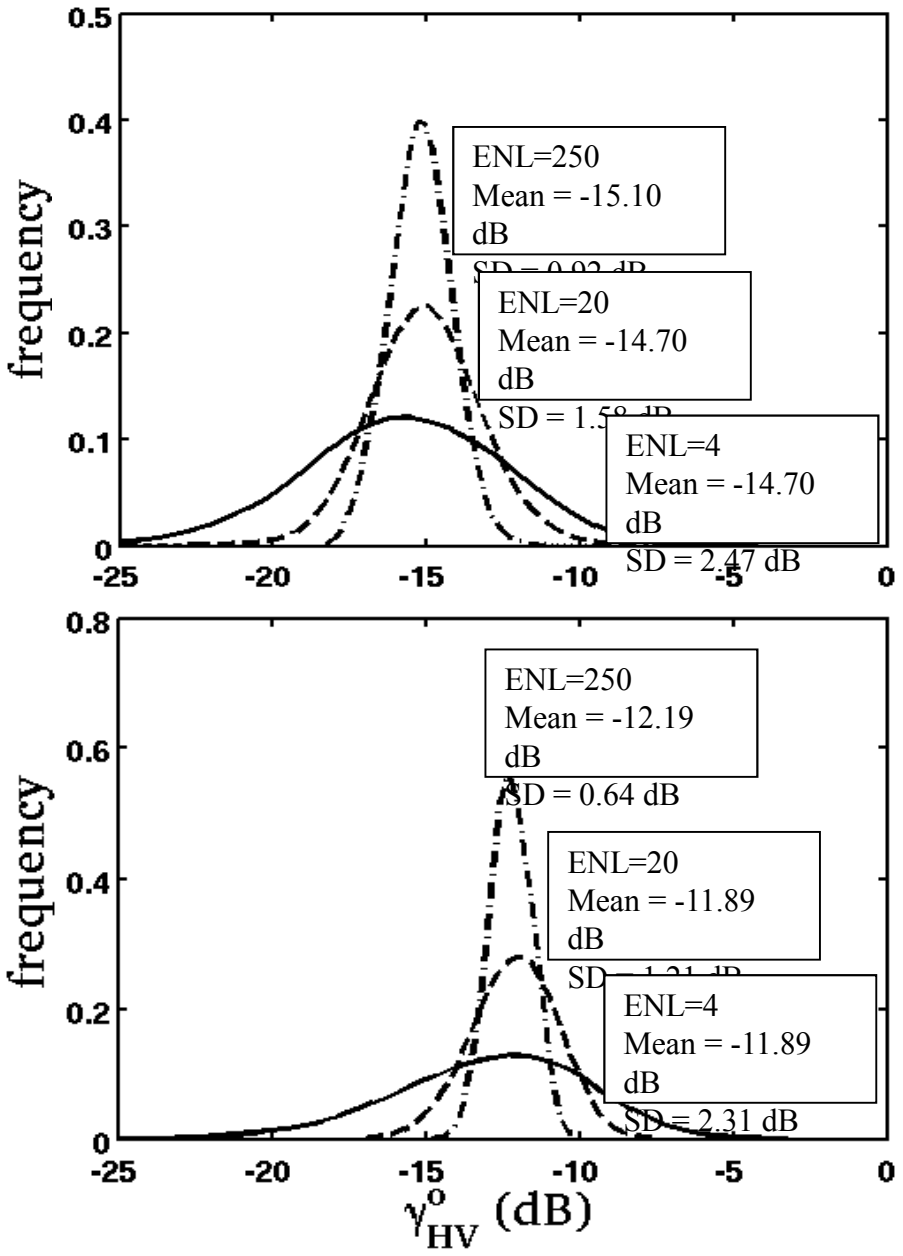



After calibration



# Multitemporal filtering



# In situ ground data collection

- Campaign from 15 January to 5 March 2012 by Mesa-Consult (REDDAF project)
- CESBIO team(3): 18-28 January for plot selection

- 21 plots
- Plot size: 1 ha,
- Geolocation accuracy (max of 10 meters)
- Plot parameters: species composition, forest structure, understory conditions, average biomass and error from biomass distribution
- Individual tree measurements (biomass, tree height, allometric equation,DBH, wood density and basal area)
- Ancillary data (soil type, slope, elevation, climate data, management)

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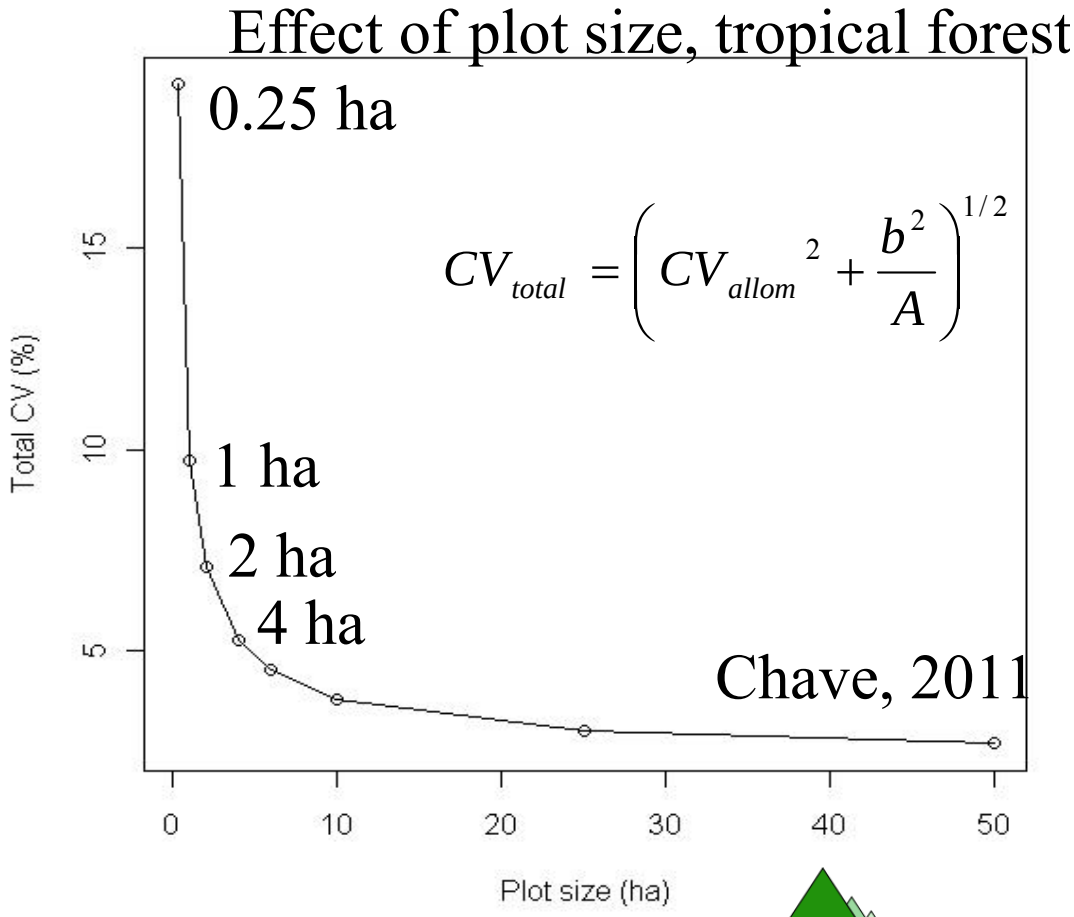
# In situ ground data collection

**In situ plot size requirement:**

**. At least 1ha in tropical forest for for natural variabilty**

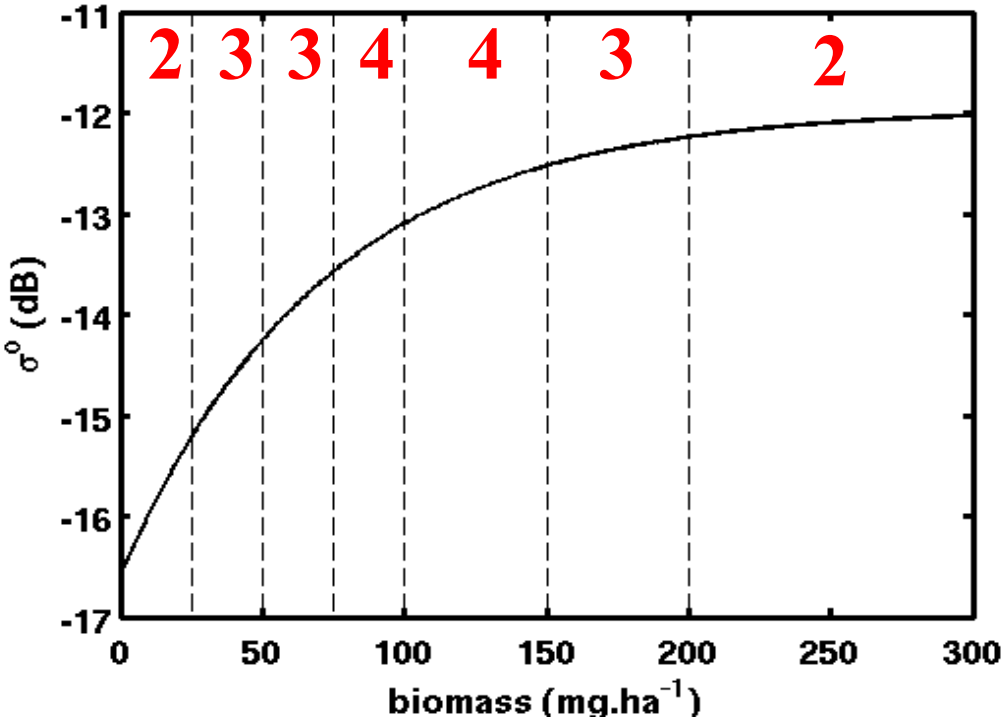
**. At least 1 ha for radar validation because of speckle effect**

**- Existing plots are not adapted**

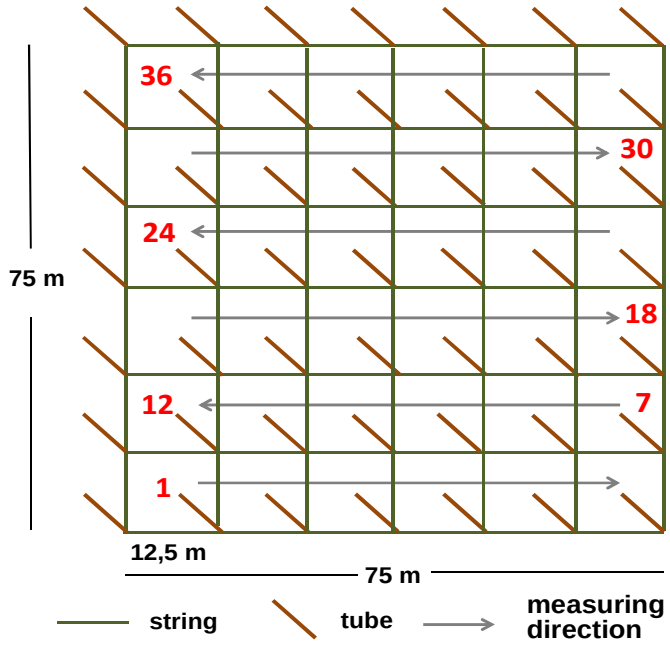


# In situ plot data collection

## Number of plots




## 1 ha plot




Allometry(Chave et al. 2005) will be used:

***Dry forests:*** $AGB = \exp\{-2.187+0.916*\ln(RD^2H)\} \equiv 0.112 * (RD^2H)^{0.916}$

***Moist forests:*** $AGB = \exp(-2.977 + \ln(RD^2H)) \equiv 0.0509 * RD^2H$

Where D: dbh [cm]; R: wood specific gravity [g/cm$^3$], H: height [m]



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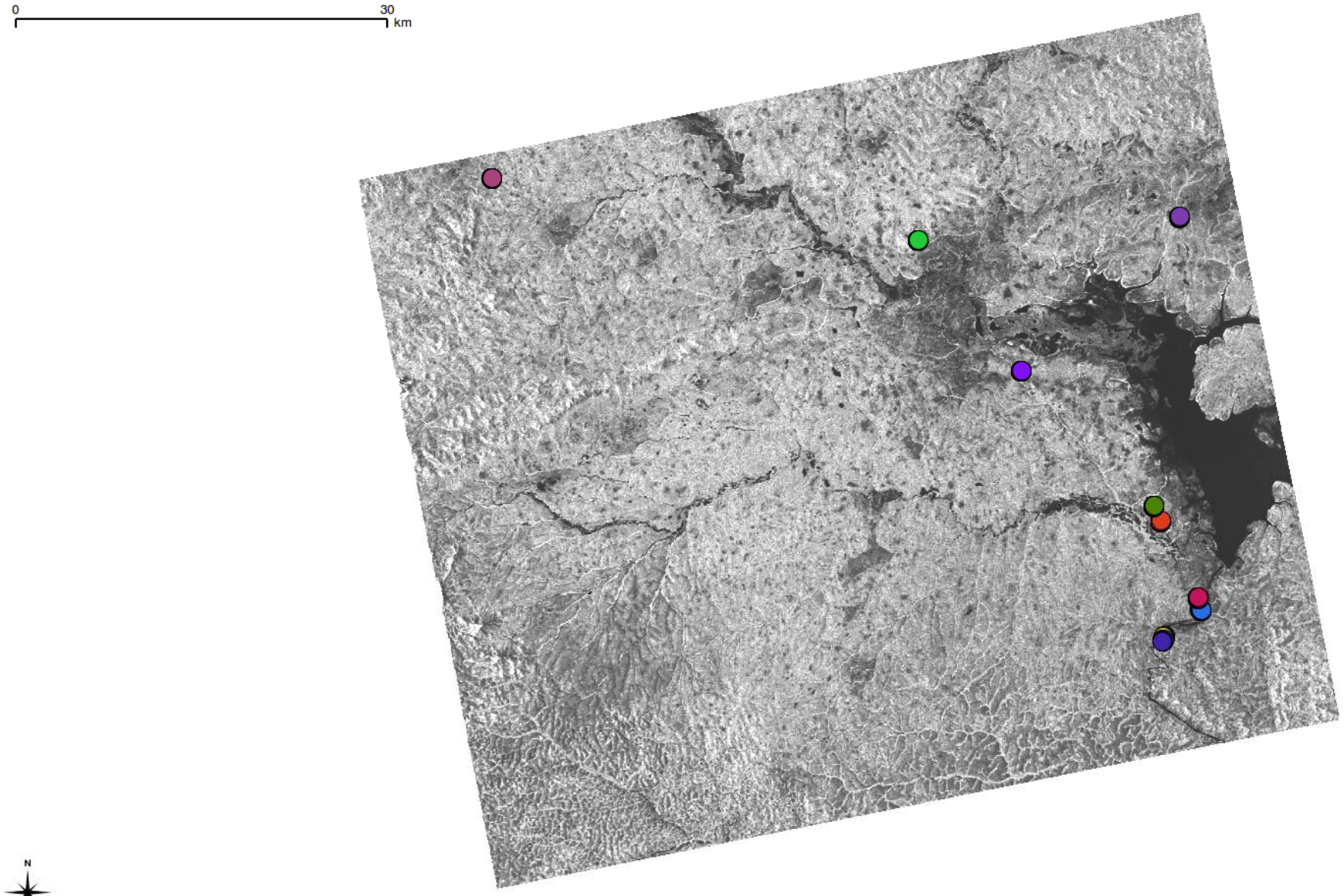
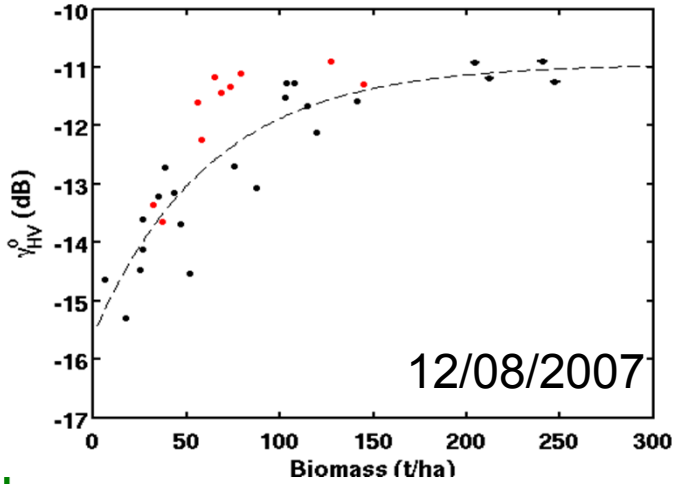
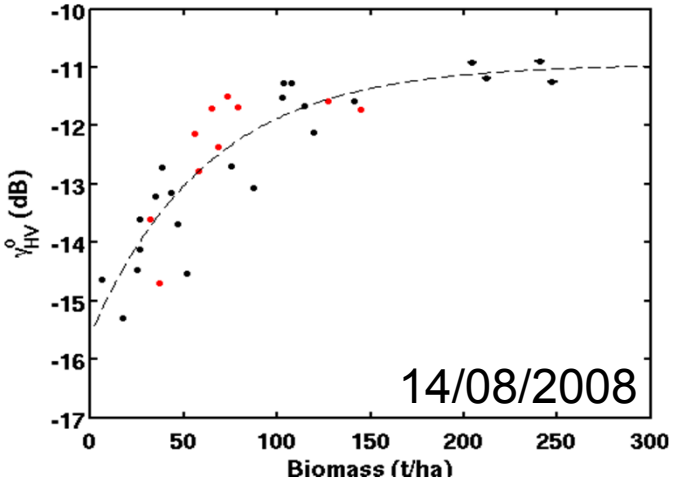


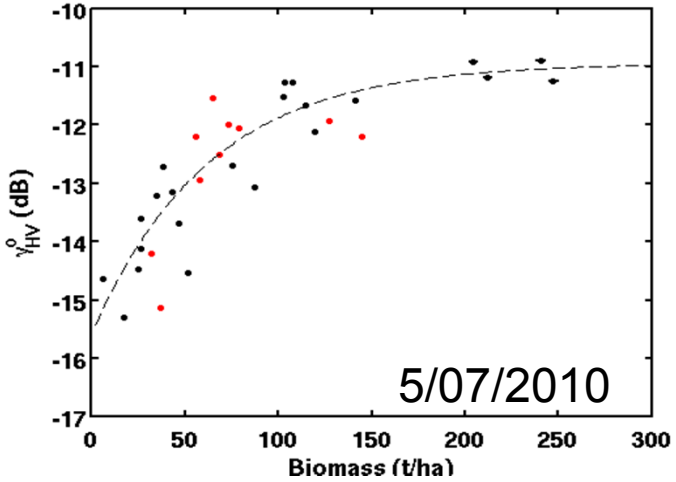

Ground data collection:January-March 2012, Mesa-Consult & CESBIO

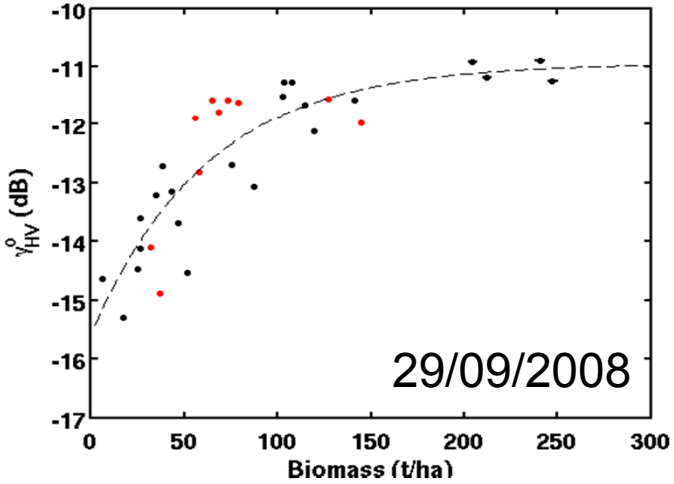
DBH measurements

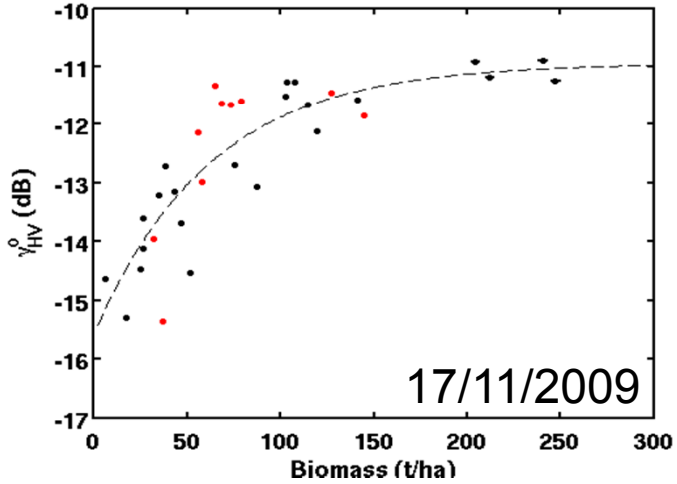
# Model : $\gamma^{o}_{HV}$



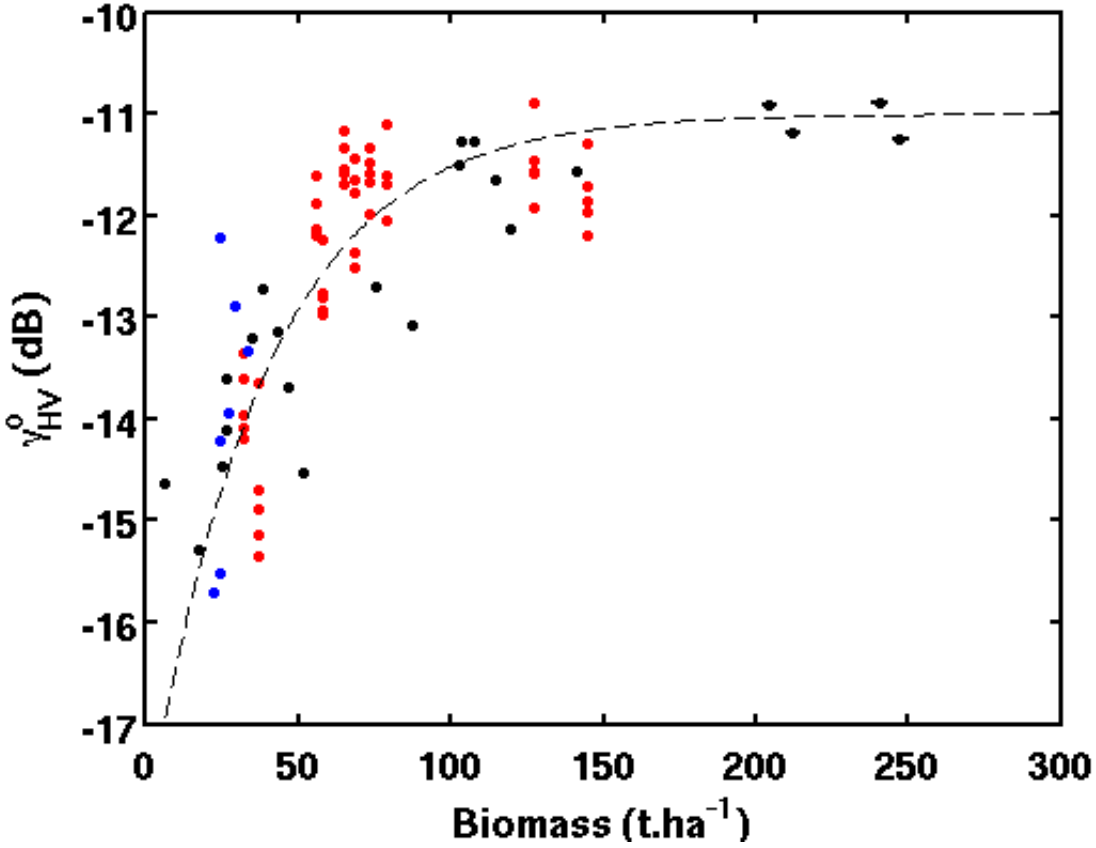



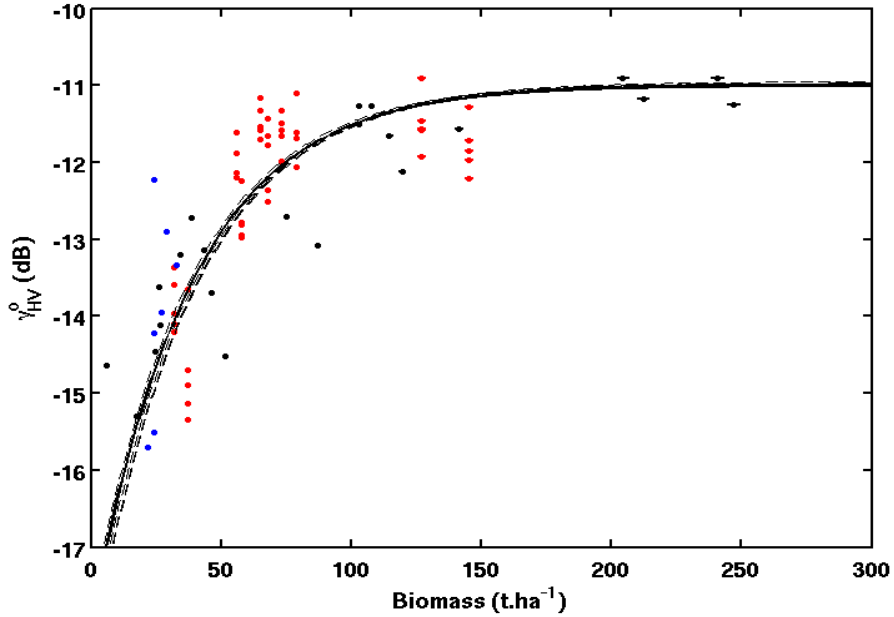




Red: Cameroon Adamawa
Black: Cameroon
Mitchard et al., 2011

# Model : $\gamma^{o}_{HV}$



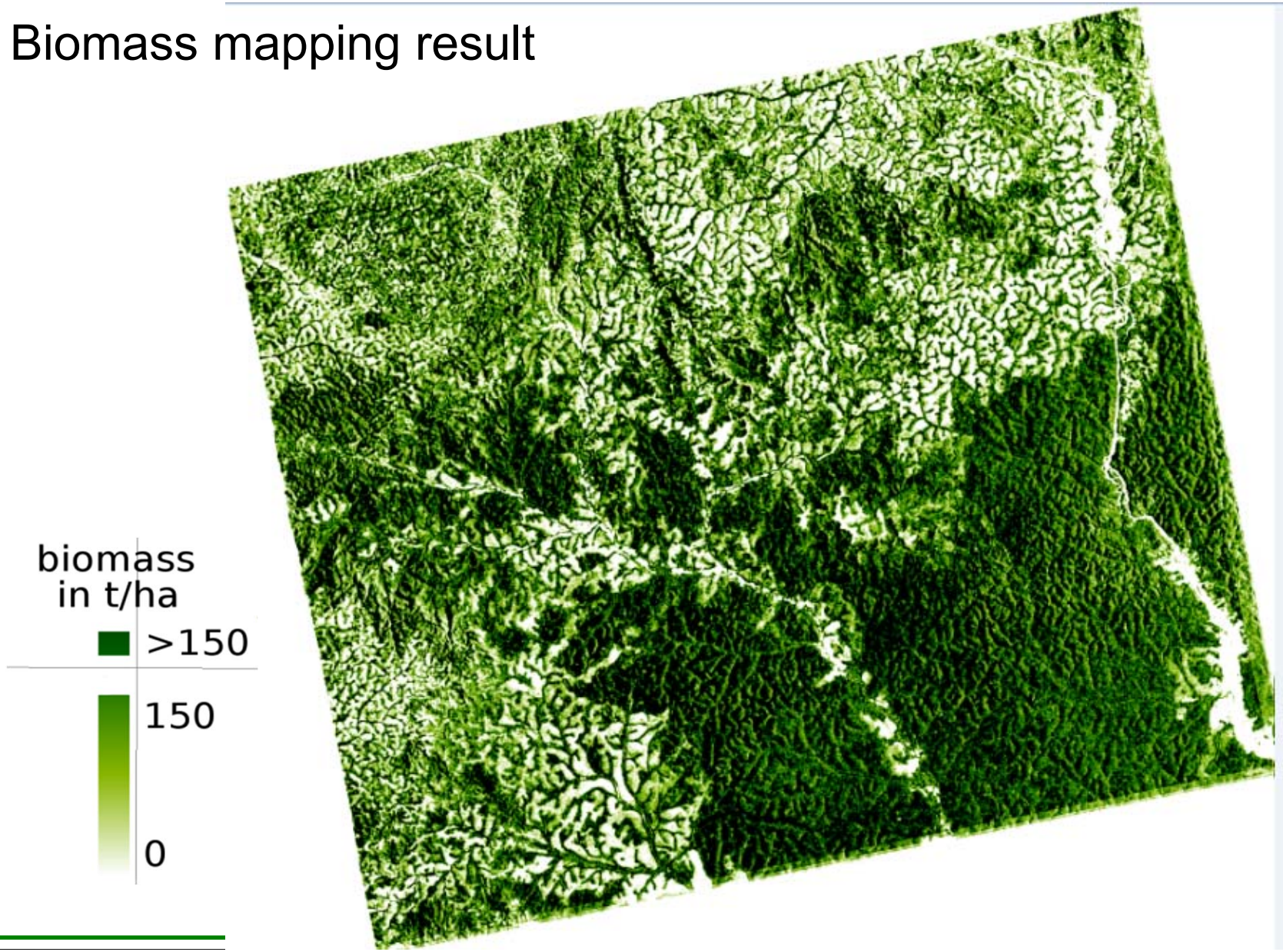

Red: Cameroon Adamawa multidates 2007-2010 with ground data 2012
Black: Cameroon Mitchard et al., 2011
Blue: Vietnam Hoa Binh



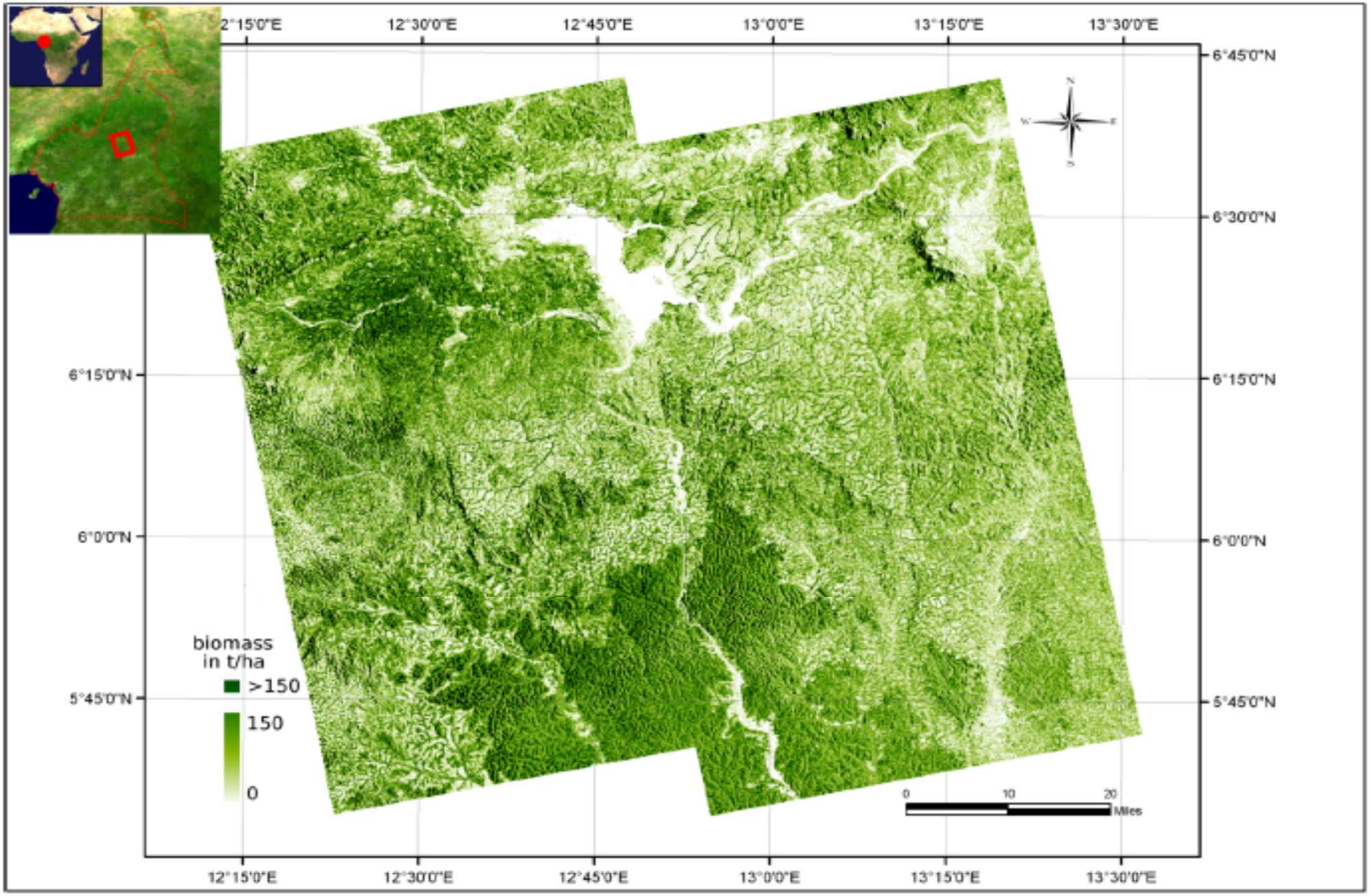

$$AGB = \frac{1}{c} \times - ln\left[1 - \frac{ALOSHV_{gamma^o} - a}{b}\right].$$

| | a | b | c | $r_p$ | RMSE (t.ha$^{-1}$) |
|---|---|---|---|---|---|
| 12/08/2007 | -18.4 | 7.5 | 0.026 | 0.81 | 36.5 |
| 14/08/2008 | -18.4 | 7.4 | 0.026 | 0.88 | 32.2 |
| 29/09/2008 | -18.2 | 7.3 | 0.026 | 0.87 | 33.1 |
| 17/11/2009 | -17.8 | 6.8 | 0.026 | 0.86 | 33.9 |
| 05/07/2010 | -18.5 | 7.5 | 0.026 | 0.88 | 33.5 |
| Total | -18.0 | 7.1 | 0.026 | 0.75 | 33.7 |

# Biomass mapping result

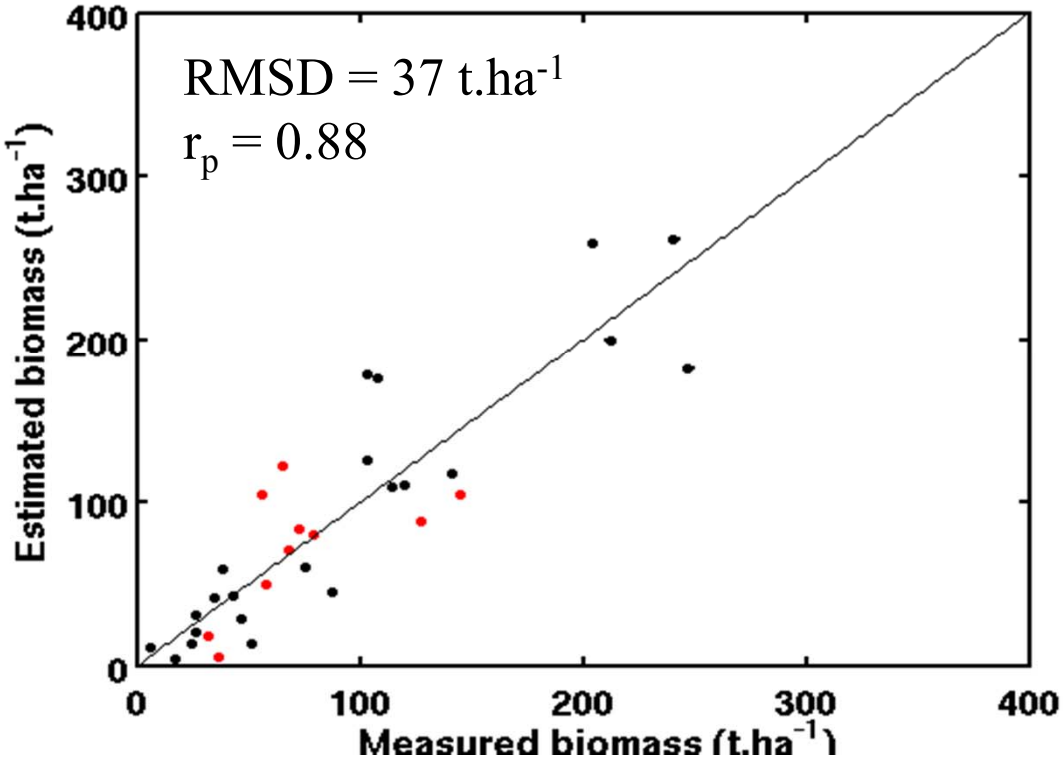


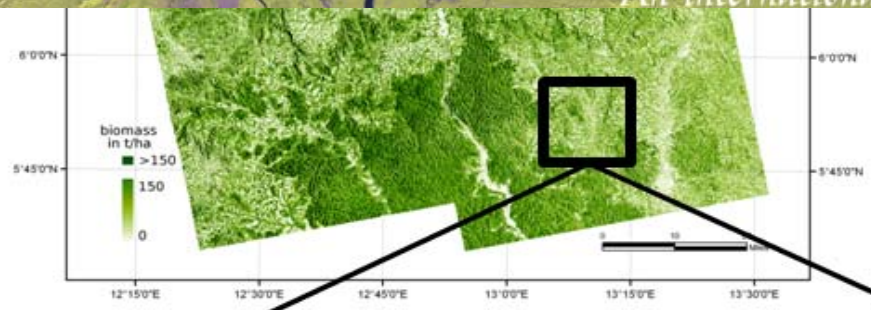
# Biomass map of the Adamawa region using PALSAR



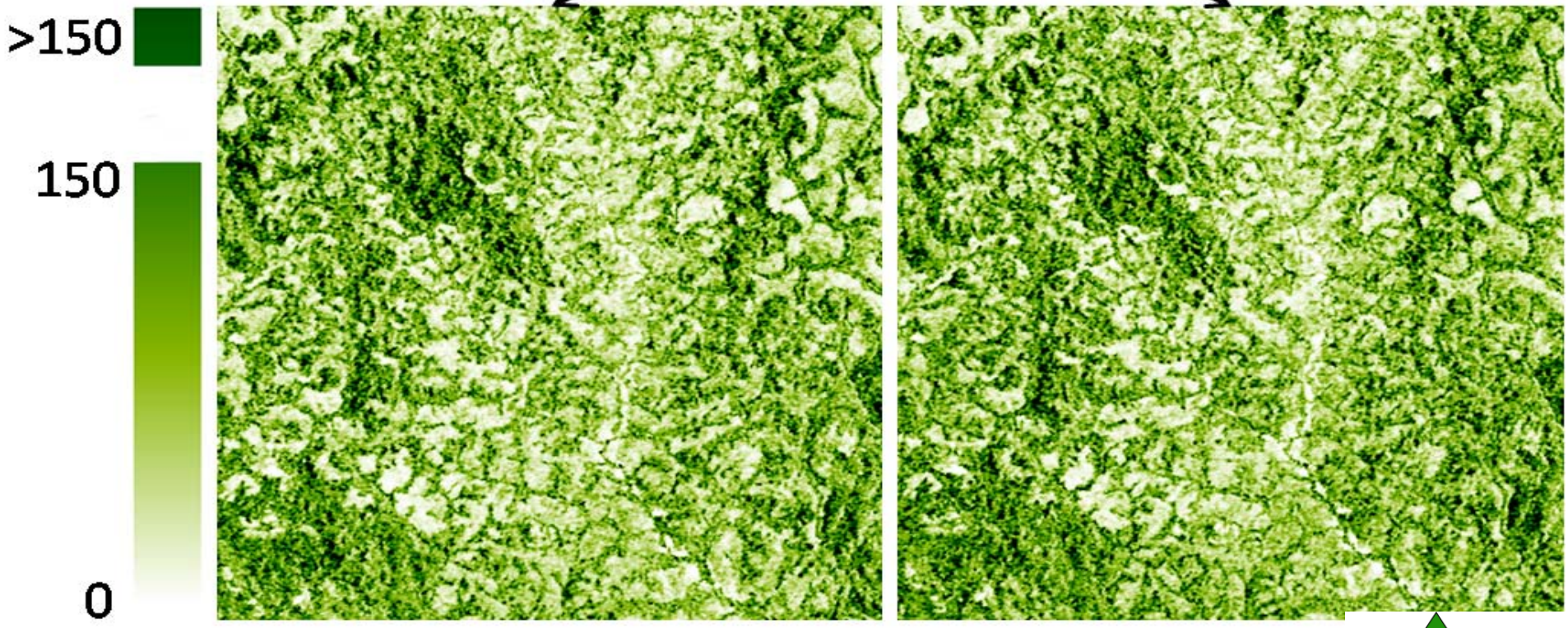
500 realizations

# Bayesian inversion results using $\gamma^{o}_{HV}$






July 26, 2007 (left) June 18, 2010 (right). The area (15 km x 17 km) is on the East part of the Mbam and Djerem National Park.




No visible change in this less populated ar

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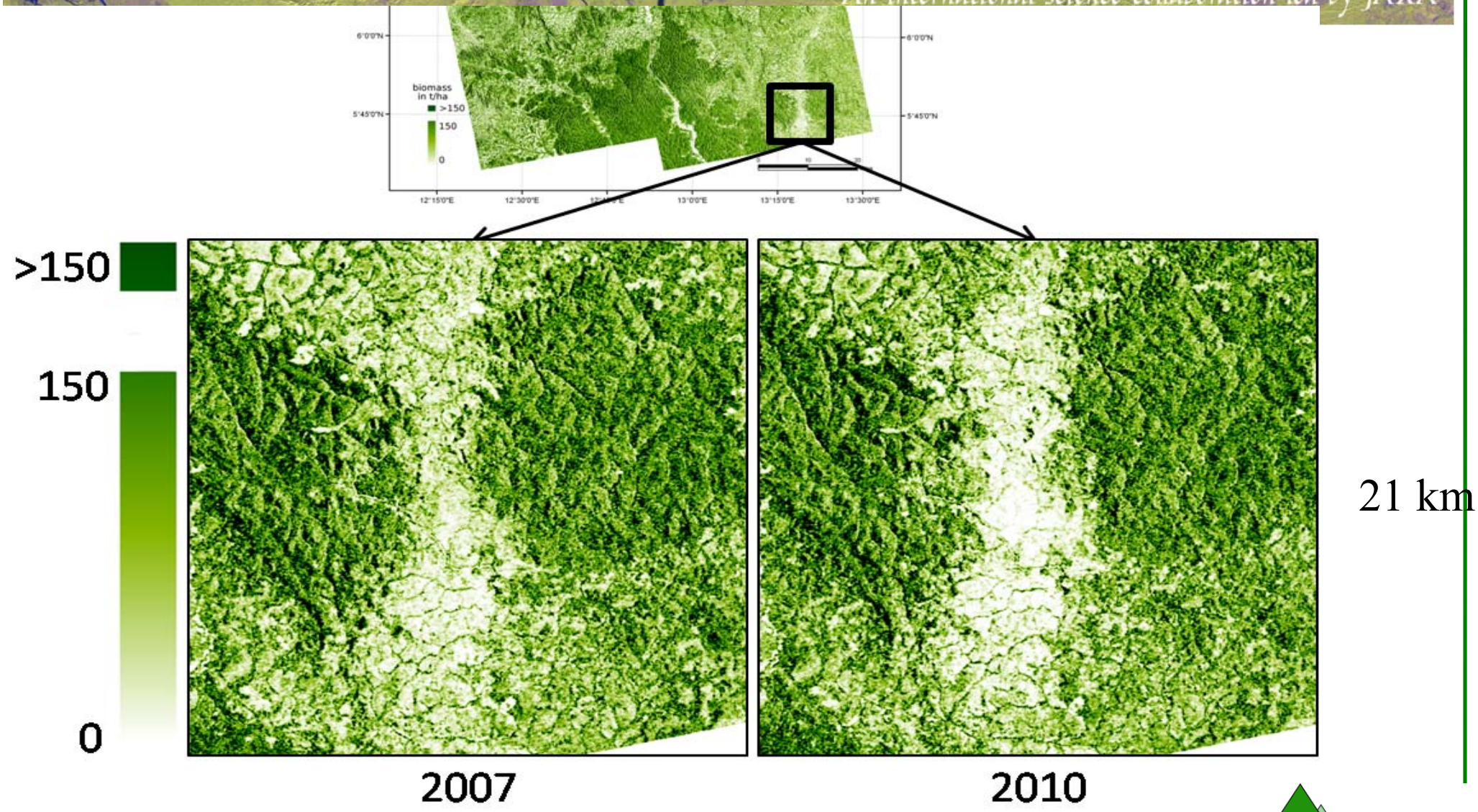
# Change in biomass




Change of biomass in the Pangar Djerem Reserve edges of the forest:



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# Deliverables for Cameroon

- Forest cover and cover change in Adamawa (31.04.2012)
- Forest biomass in Adamawa (31.04.2012)
- In situ data under CESBIO REDDAF project (31.03.2013)

# Support to JAXA's global forest mapping effort

The project can support JAXA's global forest mapping effort in Cameroon and in Vietnam and help improve and validate the JAXA forest cover maps.

Ground truth data that will be shared with JAXA

- Vietnam: Ground data at prototype provinces: Hoa Binh , and planned provinces in the South and in the Centre
- Cameroon: Data from REDDAF (Adamawa region of forest-savanna)

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Thank you JAXA !