ALOS

K&C Initiative
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K&C Phase 4 – Final Report

Measuring above ground biomass and changes over Brazilian tropical secondary forests and savanna woodlands (Cerrado) using L-band SAR data

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Project outline and objectives

Assess the sensitivity of L-band SAR data to forest above ground biomass (AGB) in lower-carbon tropical regions of **Brazil** : **secondary forests** and savanna woodlands (***Cerrado)***

1. ***Mapping the age of tropical secondary forests as a proxy for AGB***

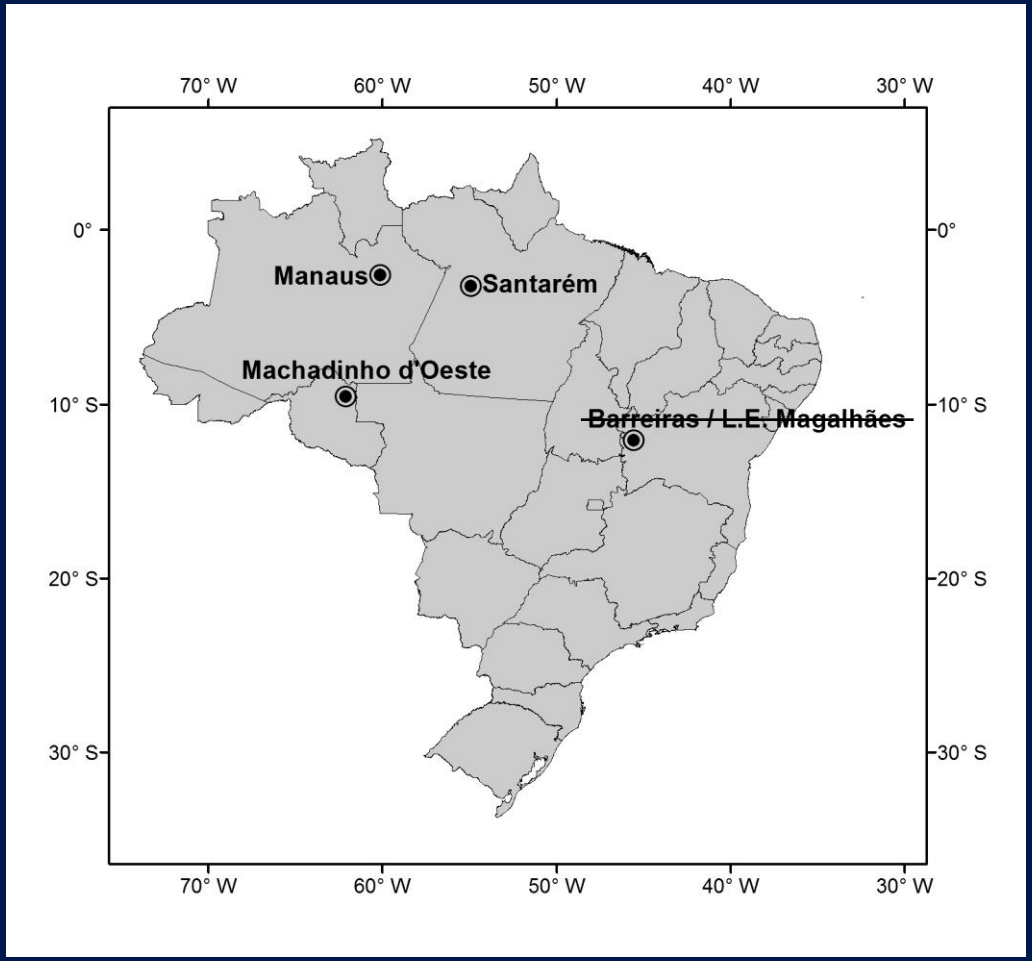
2. ***Mapping AGB in tropical secondary forests ~~and Cerrado~~***

Support of K&C Thematic Drivers

- Tropical secondary forests are an important carbon sink, partially offsetting gross emissions due to land use change (mainly from deforestation), and also important at restoring biodiversity

- Still high uncertainty in the contribution of secondary forests to the global carbon budget (~50% in South America – Pan et al., 2011)

Study areas



Secondary forests

- Manaus (Amazonas)
- Santarém (Pará)
- Machadinho d'Oeste (Rondônia)

~~Savanna woodland (*Cerrado*)~~

- ~~Barreiras (Bahia)~~
- ~~Luis Eduardo Magalhães (Bahia)~~

Results and significant findings

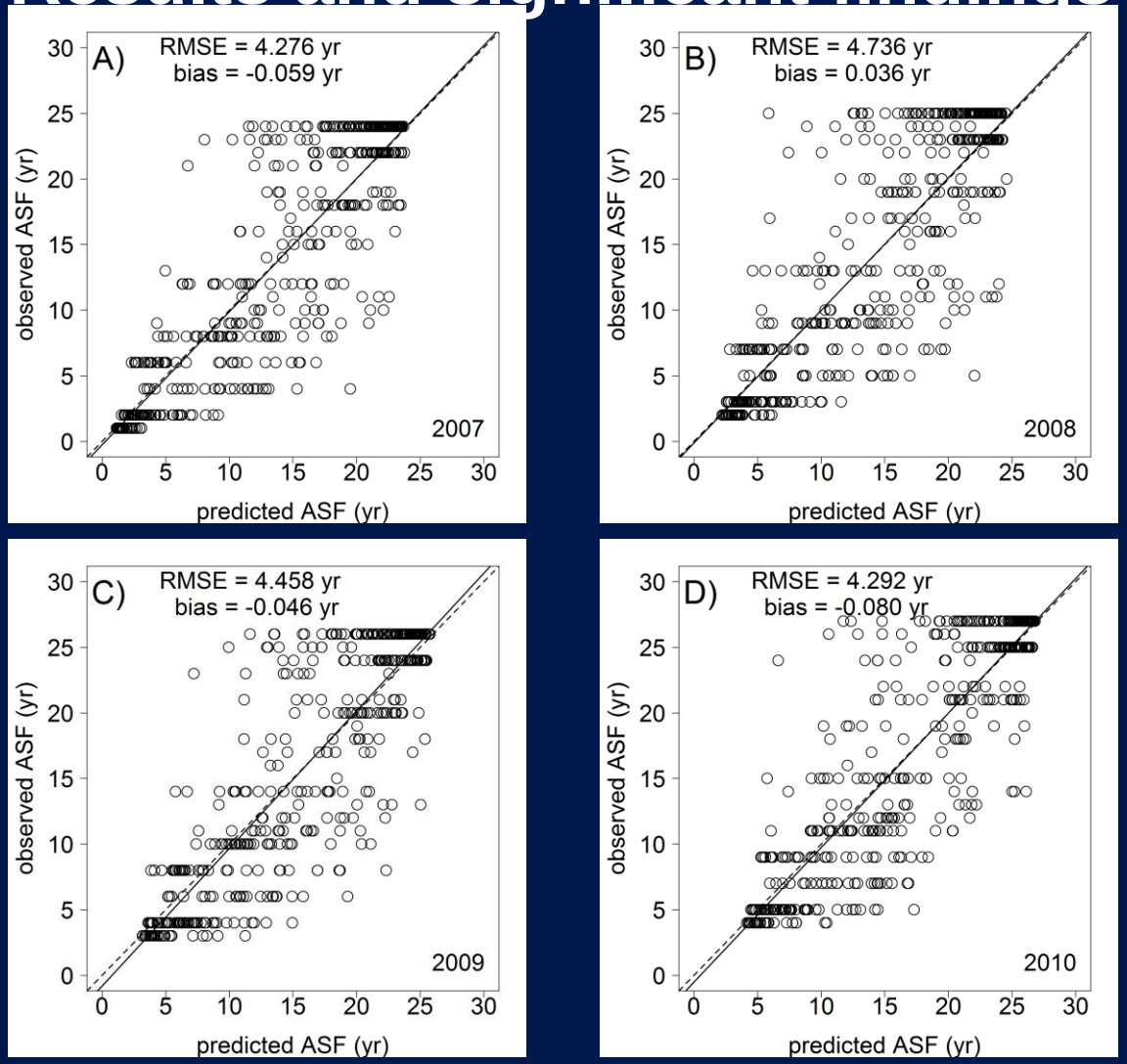
1. Mapping the age of tropical secondary forests

What is the capability of optical and L-band SAR data to discriminate the age of tropical secondary forests?

- Access to precise location of areas with secondary forests of known age
- ALOS PALSAR 2007-2010 catalogue: dual-pol (HH+HV) level 1.1
- Landsat 5 TM surface reflectance data 2007-2010 (USGS)
- Regression: machine learning (random forests)

Results and significant findings

1. Mapping the age of tropical secondary forests



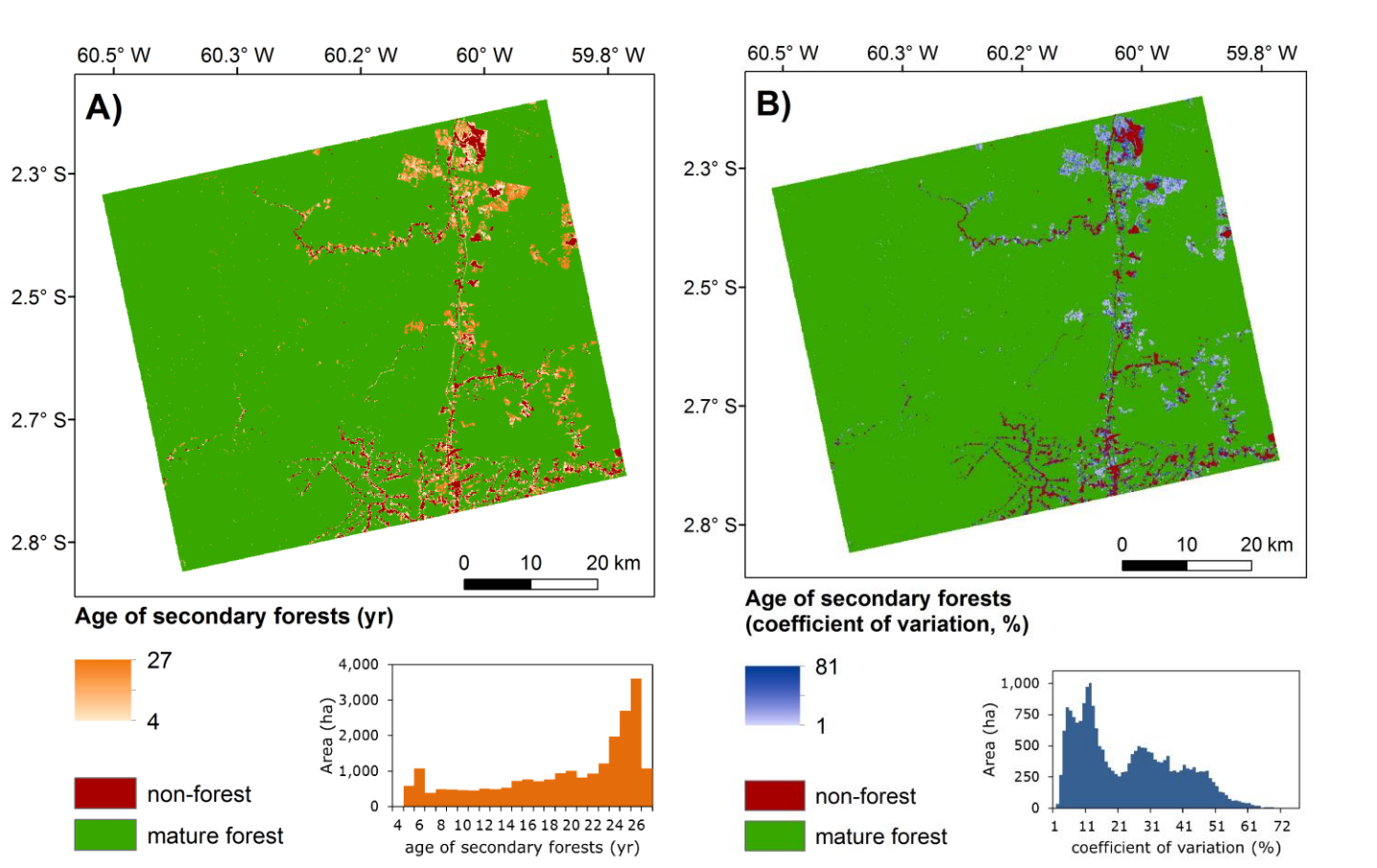
- RMSE ~4 yr and on averaged unbiased
- However, bias highly dependent on the age class
- Overestimation in younger age classes and underestimation in older age classes

Carreiras et al. *Remote Sens Environ* **2017**

Results and significant findings

1. Mapping the age of tropical secondary forests

Manaus



Carreiras et al. *Remote Sens Environ* **2017**

Results and significant findings

1. Mapping the age of tropical secondary forests

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Mapping major land cover types and retrieving the age of secondary forests in the Brazilian Amazon by combining single-date optical and radar remote sensing data

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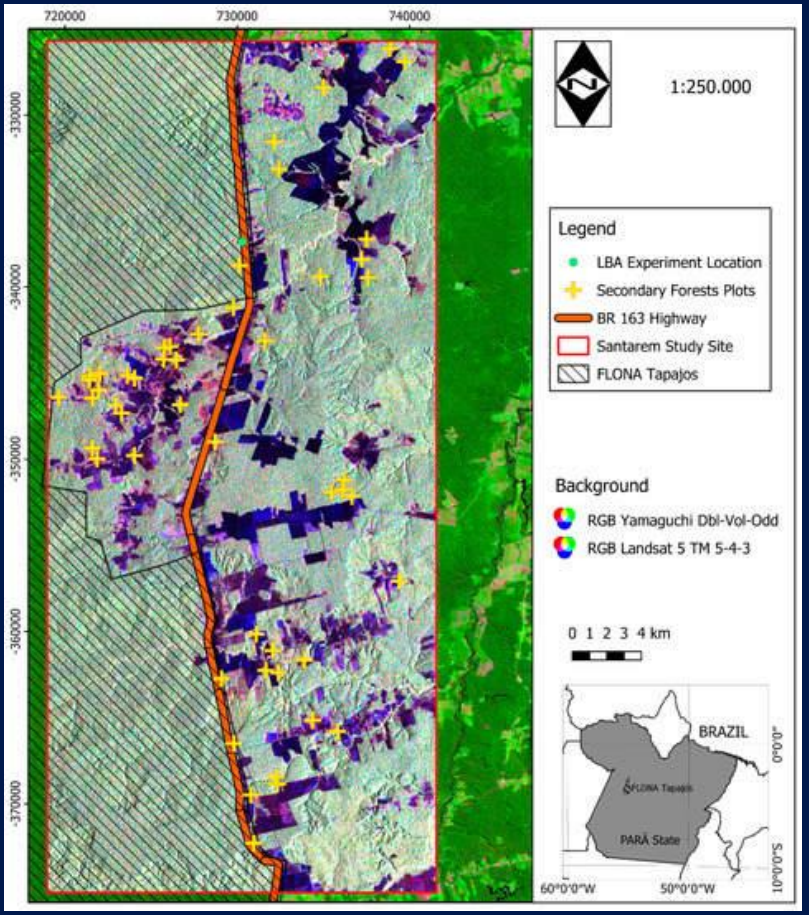
ABSTRACT

Secondary forests play an important role in restoring carbon and biodiversity lost previously through deforestation and degradation and yet there is little information available on the extent of different successional stages. Such knowledge is particularly needed in tropical regions where past and current disturbance rates have been high but regeneration is rapid. Focusing on three areas in the Brazilian Amazon (Manaus, Santarém, Machadinho d'Oeste), this study aimed to evaluate the use of single-date Landsat Thematic Mapper (TM) and Advanced Land Observing Satellite (ALOS) Phased Arrayed L-band Synthetic Aperture Radar (PALSAR) data in the 2007–2010 period for i) discriminating mature forest, non-forest and secondary forest, and ii) retrieving the age of secondary forests (ASF), with 100 m × 100 m training areas obtained by the analysis of an extensive time-series of Landsat sensor data over the three sites. A machine learning algorithm (random forests) was used in combination with ALOS PALSAR backscatter intensity at HH and HV polarizations and Landsat 5 TM surface reflectance in the visible, near-infrared and shortwave infrared spectral regions. Overall accuracy when discriminating mature forest, non-forest and secondary forest is high (95–96%), with the highest errors in the secondary forest class (omission and commission errors in the range 4–6% and 12–20% respectively) because of misclassification as mature forest. Root mean square error (RMSE) and bias when retrieving ASF ranged between 4.3–4.7 years (relative RMSE = 25.5–32.0%) and 0.04–0.08 years respectively. On average, unbiased ASF estimates can be obtained using the method proposed here (Wilcoxon test, p-value > 0.05). However, the bias decomposition by 5-year interval ASF classes showed that most age estimates are biased, with consistent overestimation in secondary forests up

Results and significant findings

2. Mapping AGB in tropical secondary forests



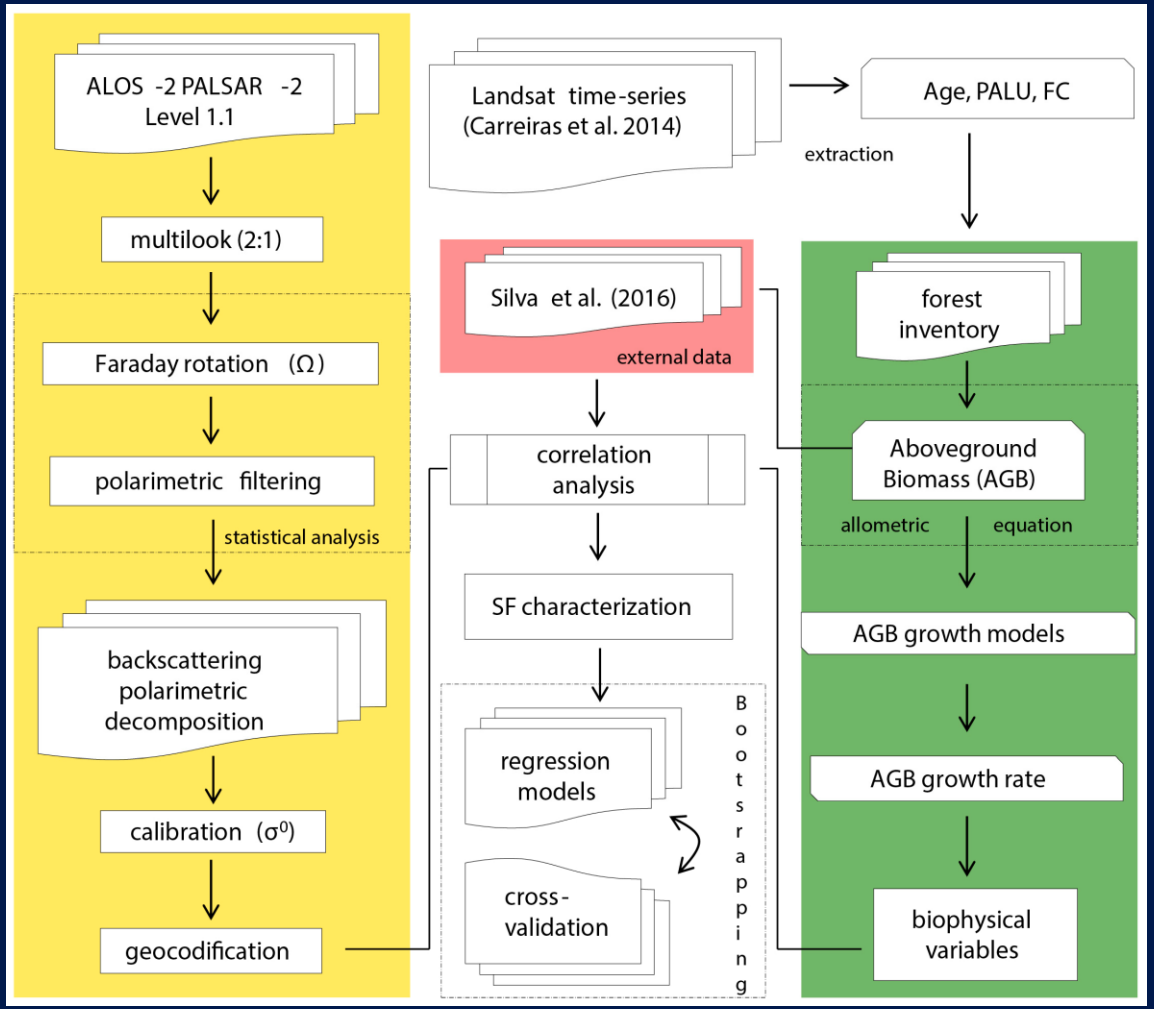
Cassol et al. *Remote Sens* **2019**

- **Santarem, 2015, 16 nested plots:** 100x60 m, min DBH = 5 cm; secondary forests >16 yr
- **Santarem, 2012, 26 plots**: 23 20x50 m (min DBH 5 cm) + 3 25x100 m (min DBH 10 cm); secondary forests < 16 yr (Silva et al., 2016)

- **2 quad-pol ALOS-2 scenes (February 2015)**

Results and significant findings

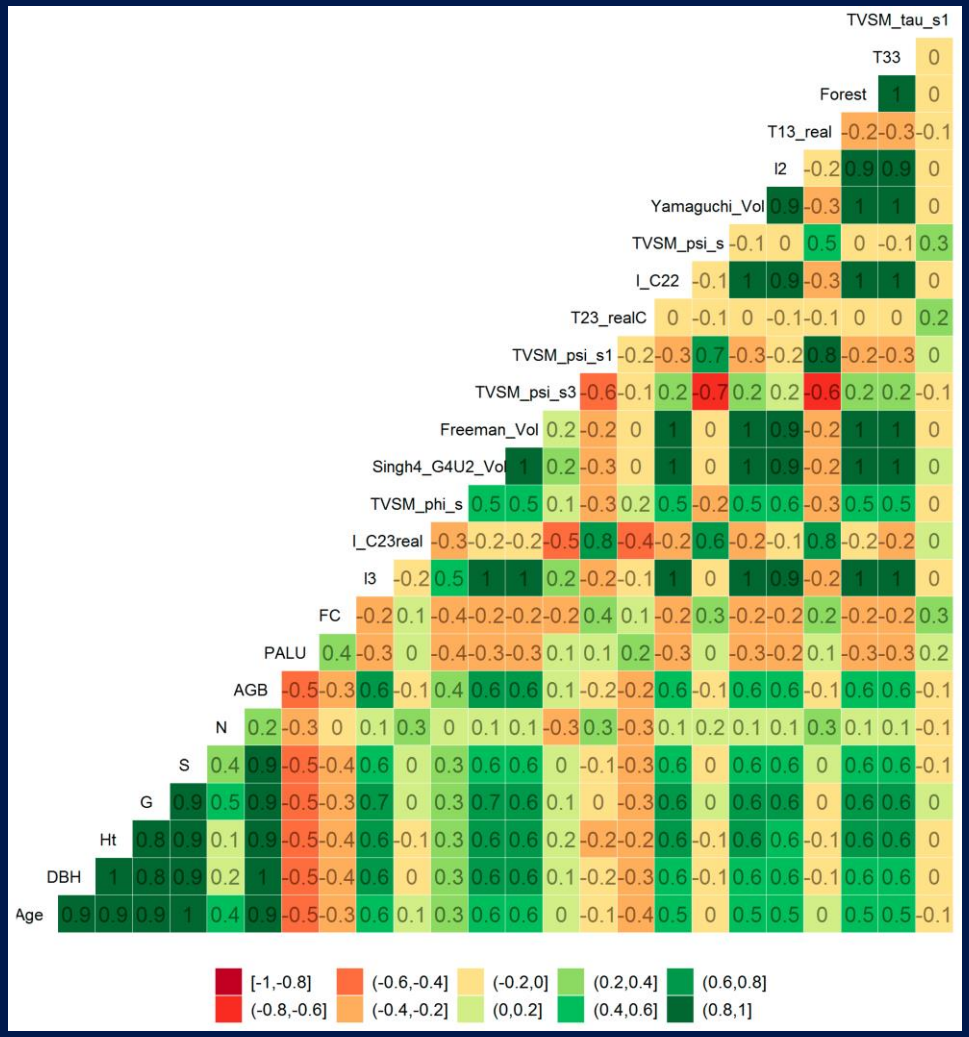
2. Mapping AGB in tropical secondary forests



Cassol et al. *Remote Sens* **2019**

Results and significant findings

2. Mapping AGB in tropical secondary forests



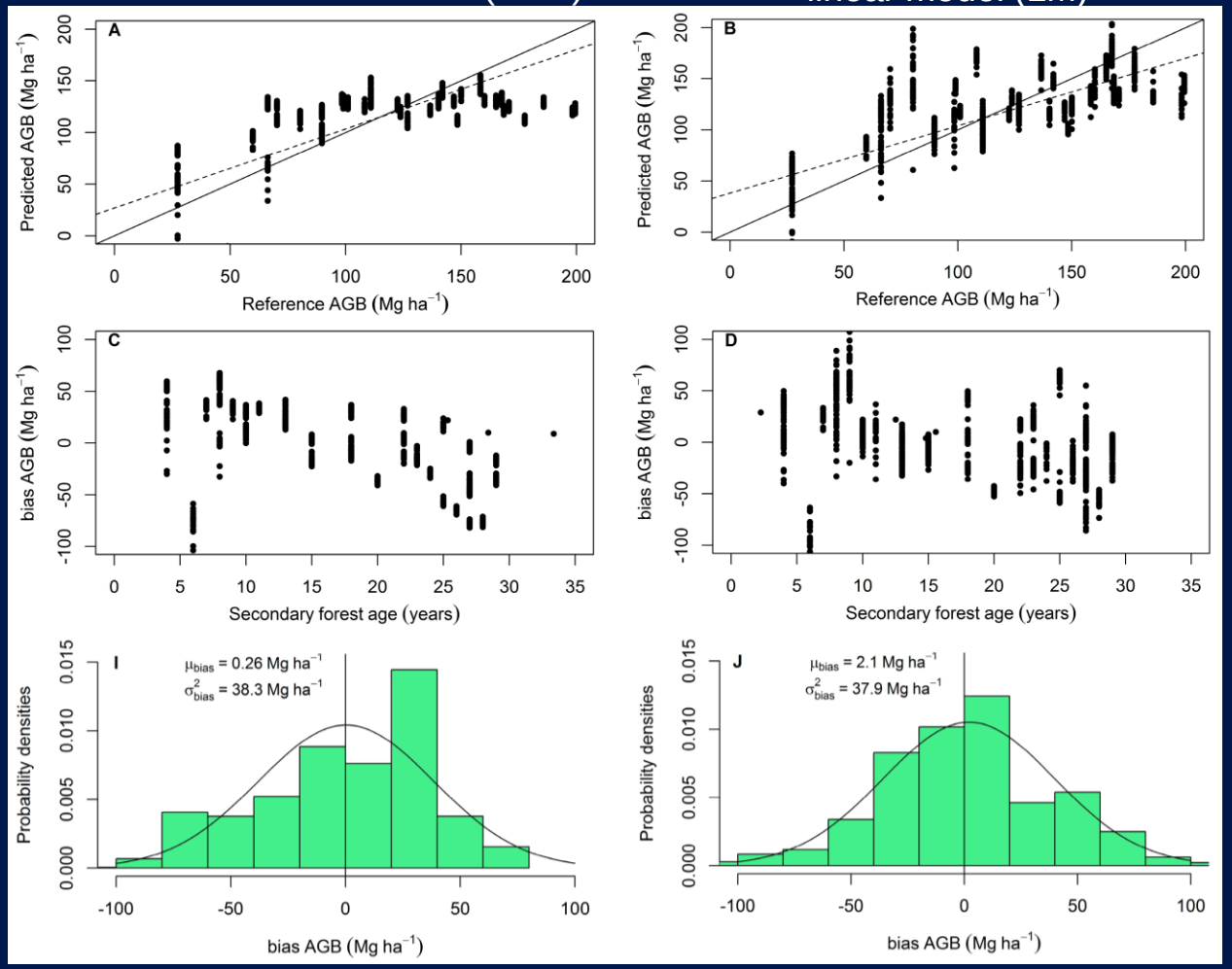
Cassol et al. *Remote Sens* **2019**

- Higher correlation (0.6) with AGB, e.g.:
  - Singh vol.
  - Freeman–Durden vol.
  - Yamaguchi vol.
- As expected, AGB was positively correlated with volumetric scattering, meaning secondary forests showed greater volumetric scattering contribution with increasing forest age

Results and significant findings

2. Mapping AGB in tropical secondary forests

non-linear model (NLM) | linear model (LM)

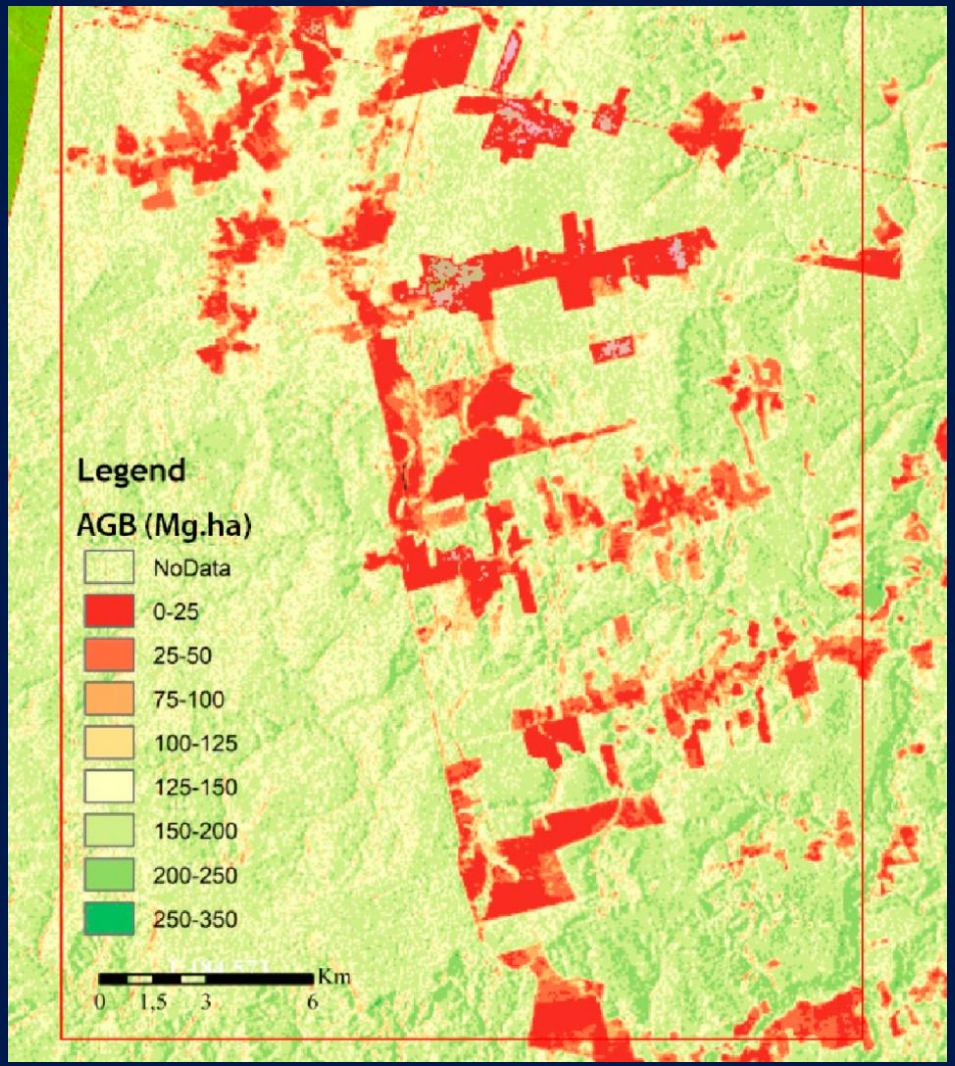


- NLM (1 predictor)
  - backscattering coefficient cross - polarized channel (σ^0 HV)
- LM (6 predictors from polarimetric decompositions from correlation filter selection)
- Similar behaviour: overestimation up to 100 Mg ha^{-1} and underestimation above this value, but more scattered in LM
- RMSE
  - NLM = 39.7±6.8 Mg ha^{-1}
  - LM = 38.7±9.8 Mg ha^{-1}

Cassol et al. *Remote Sens* **2019**

Results and significant findings

2. Mapping AGB in tropical secondary forests



Cassol et al. *Remote Sens* **2019**

Results and significant findings

2. Mapping AGB in tropical secondary forests

remote sensing
MDPI

Article

Retrieving Secondary Forest Aboveground Biomass from Polarimetric ALOS-2 PALSAR-2 Data in the Brazilian Amazon

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Abstract: Secondary forests (SF) are important carbon sinks, removing CO_2 from the atmosphere through the photosynthesis process and storing photosynthates in their aboveground live biomass (AGB). This process occurring at large-scales partially counteracts C emissions from land-use change, playing, hence, an important role in the global carbon cycle. The absorption rates of carbon in these forests depend on forest physiology, controlled by environmental and climatic conditions, as well as on the past land use, which is rarely considered for retrieving AGB from remotely sensed data. In this

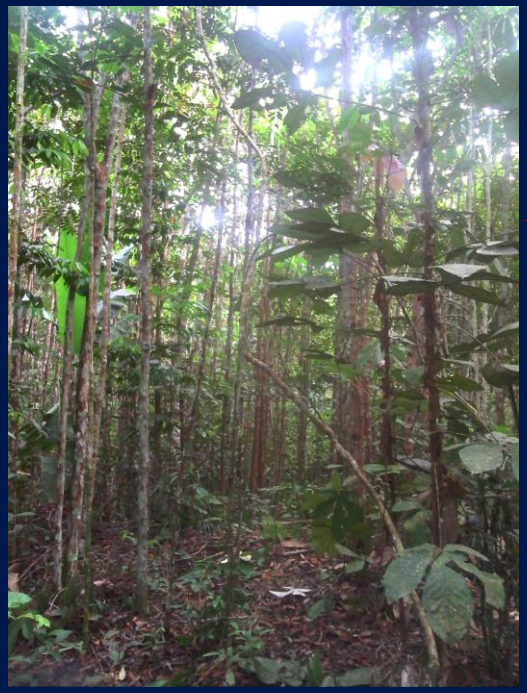
Special Issue The Kyoto and Carbon Initiative—Environmental Applications by ALOS-2 PALSAR-2

Deliverables and other output

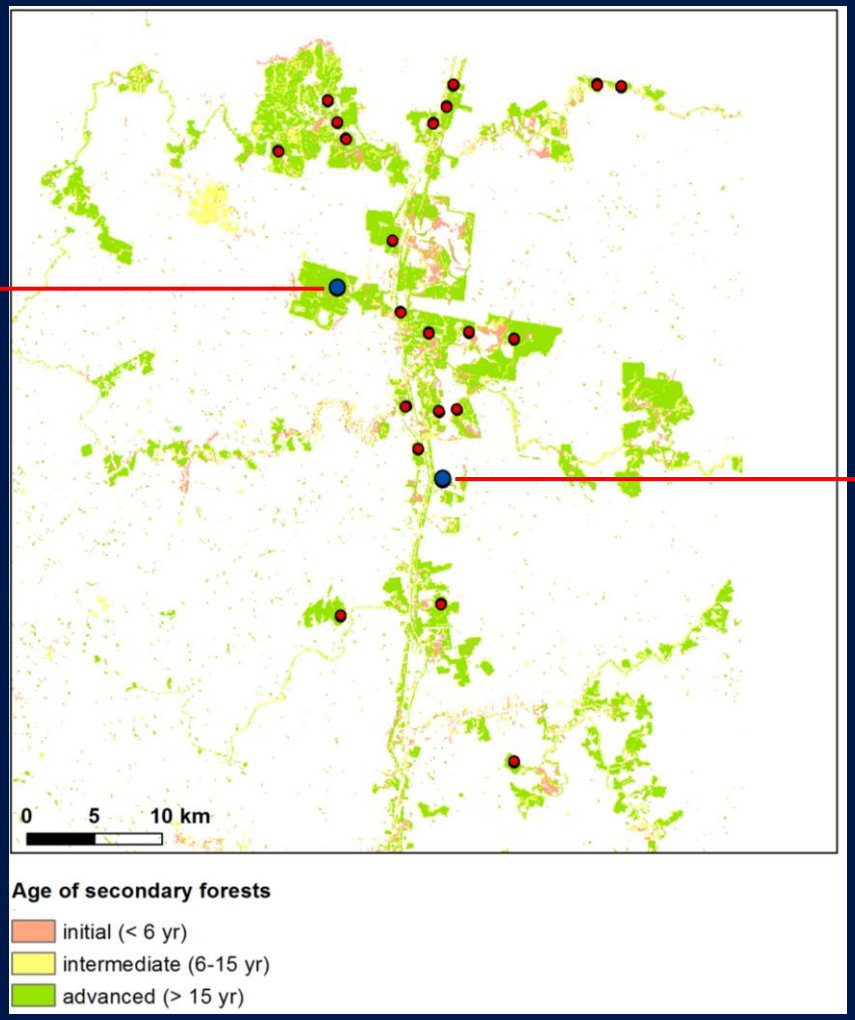
- Maps of age of secondary forests in the Amazon, including validation and error maps
- Contribution of full-pol ALOS-2 PALSAR-2 data to retrieve above-ground biomass of tropical secondary forests
- Carreiras et al. Remote Sens Environ **2017**
- Cassol et al. Remote Sens **2019**
- **Data sharing**

Data sharing

Manaus, August 2014, 23 plots measured in secondary forests



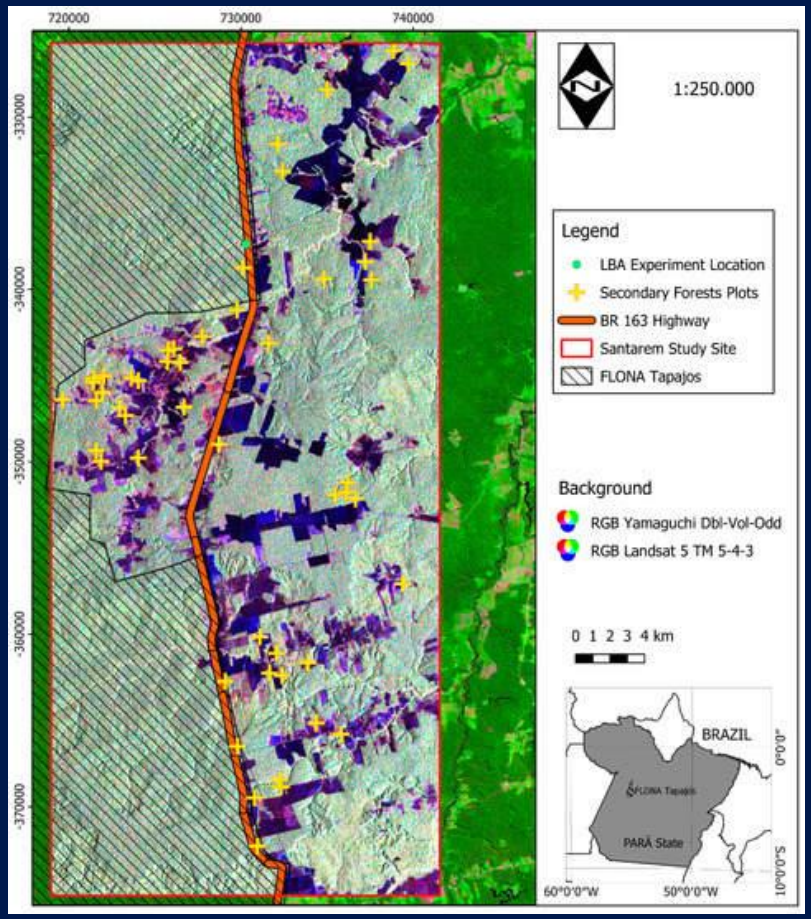
Adv22_18
19 years old



Adv12_2
22 years old

Data sharing

Santarem, August 2015, 16 plots measured in secondary forests



PALSAR/PALSAR-2 data access

- ALOS PALSAR and ALOS-2 PALSAR-2 over secondary forest downloaded

- Data made available by JAXA was enough to complete the project

Post-KC proposal

Estimating forest above-ground biomass change in East Africa from L-band SAR data

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Maurizio Santoro, GAMMA Remote Sensing AG, Switzerland
Svein Solberg, Norwegian Institute of Bioeconomy Research, Norway

Objective: Improve the retrieval of decadal forest above-ground biomass change across East Africa dry tropics using repeated observations from L-band SAR systems

Areas: Kenya, Tanzania and Mozambique

Post-KC proposal

Data requirements: PALSAR-1 and PALSAR-2 path data , level 1.1 (SLC), covering the three selected countries

Other data sources:

- PALSAR-1 and PALSAR-2 mosaics
- In situ above-ground biomass plot data

Relevance to the 4 K&C thematic drivers: Estimates of the size of forest carbon sources and sinks are urgently needed but are still highly uncertain because we have very poor knowledge about the amount of carbon stored in tropical forests and its changes with time.

Expected outcomes and deliverables:

- forest AGB change algorithms based on PALSAR mosaic and path data
- forest AGB change maps driven by PALSAR mosaic and path data