TROPICAL FOREST HEIGHT AND ABOVE GROUND BIOMASS ESTIMATION IN INDONESIA WITH THE USE OF POL-INSAR DATA - FIRST RESULTS

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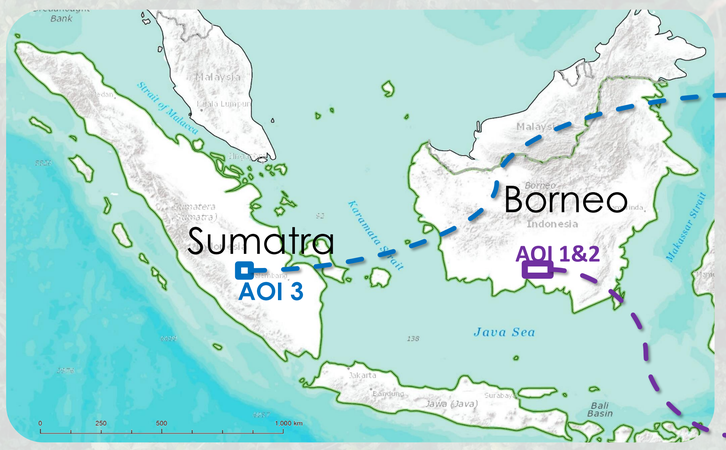
Abstract

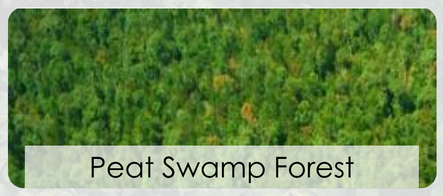
The aim of this study is to calculate **canopy height** (CH) **and above ground biomass** (AGB) in the tropical peat swamp forests of Central Kalimantan, Borneo, using a methodology based on **polarimetric SAR interferometry** (Pol-InSAR) data. SAR datasets consisting of C-band acquisitions from Sentinel-1 and Radarsat-2, as well as synergistic X-band images created from TanDEM-X and TerraSAR-X CoSSC (co-registered single look slant-range complex) data, are compared. Forest height is retrieved using a DEM differencing approach conducted with the SNAP software from the European Space Agency (ESA). The reference data is based on an extensive CH and AGB database created from existing historical forest inventories, including LiDAR measurements, alongside more recent inventories from on the ground and drone campaigns in 2016. It can be shown, that the spatial shift due to differing effective baselines together with too long temporal baselines introduce large errors during DEM generation. Only with optimal conditions from some CoSSC images it is possible to produce reliable DEMs and thus AGB estimations.

Introduction / Objective

Above ground biomass (AGB) is an essential parameter for modeling carbon dioxide (CO2) and thus climate change, making it essential to estimate this parameter as exactly as possible. Radar remote sensing allows canopy height estimation and biomass modeling over huge areas. Conventional radar remote sensing backscatter methods are limited due issues such as "biomass saturation" at levels above 150 t/ha (depending on the wavelength) and is thus unable to provide sufficient biomass estimation in tropical forests with very high biomass, whereas the Pol-InSAR method allows modelling ABG at levels also in regions with higher biomass (Vyjayanthi et al. 2008).

The aim of this project is to estimate forest height and AGB and its changes in tropical peat swamp forests in Central Kalimantan on Borneo and in lowland forests in Sumatra whereby the focus lies on the synergistic use of X- and C- band Pol-InSAR data. Forest height is retrieved using different approaches conducted with SNAP from European Space Agency (ESA), testing different wavelengths, beam modes, baselines, and polarizations. An extensive canopy height and AGB database from existing forest inventories and LiDAR measurements served alongside newly-acquired forest inventories and airborne mission dates as reference data.





Sumatra

- **Tropical lowland forest**
- Mainly **dipterocarps** (60% endemic)
- Forest height up to **45 m, max. 60 m**

Borneo

- **Tropical peat swamp forest** with **peat deposits** up to **20 m**
- **Forest height** up to max. **35 m**
- Intensive managed logging from end 70s - mid 90s
- Ex-Mega Rice Project (Ex-MRP)

Methods

To estimate canopy height and AGB in the tropical peat swamp forest, data of the different SAR sensors Sentinel-1, Radarsat-2 as well as TanDEM-X and TerraSAR-X CoSSC are used. The Reference data is based on field inventories including LiDAR measurements from the ground and drone campaigns in 2016.

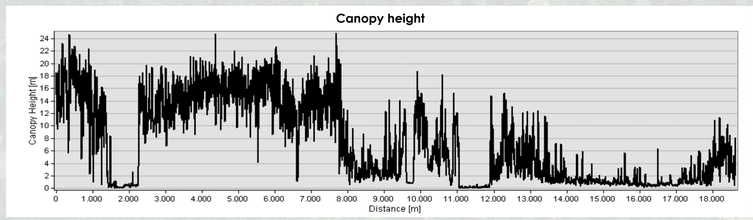
The processing of the SAR data is done in SNAP. First of all a radiometric calibration and speckle reduction is applied. Afterwards a co-registration of a pair of overlapping images, with one image as master and the other one as slave, should be done to fuse "a coherent and incoherent correlation approach supported by geometrical predictions and resampling of the slave onto the master" (Fritz et al. 2011). The co-registered image is than used to generate an interferogram of the two datasets. To exclude low frequent components in the interferogram an "interferogram flattening" is done in the interferogram generation step. Besides the flattening process the coherence, which means the stability of the backscattered SAR signal between the two images, is estimated. To reduce noise and de-correlation effects and improves fringes visibility, the Goldstein-filter from Goldstein and Werner is run on the interferogram before starting the so called phase unwrapping process. Errors often occur in this step due to low coherence and phase noise. In a next step the unwrapped information can be used for height generation using the tool "phase to elevation" within the SNAP environment. Geocoding allows a geometric correction of the final DEM. the processing was repeated for cross- and co- polarization to apply in a next step a DEM Differencing approach. Unfortunately this approach was not useful with the used sensors for which reason the canopy height was estimated due subtracting the digital terrain model (DTM) of the digital elevation model (DEM) to get surface information.

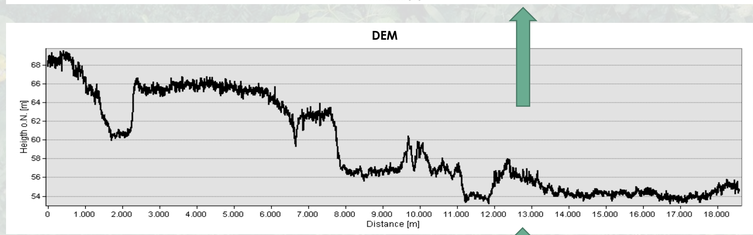
For the validation of the AGB modeled in the next step, 2000 random points will be generated and the generated AGB is compared to the AGB of the LiDAR data.

First Results

In the pictures below one can see, that a DEM generation from Pol-InSAR data is possible, at least for the dual-pol CoSSC (TS-X/TD-X) data with an effective baseline between 36 - 263 m (Table 1). DEM generation from the sensors Sentinel-1 and Radarsat-2 did not show a reliable DEM at all. Even with different acquisition parameters an improvement of the results could not be achieved. Significant differences between cross- and co-polarizations can not be found.

The DEM is used to generate the canopy heights of the study area which allows an above ground biomass modelling later on.





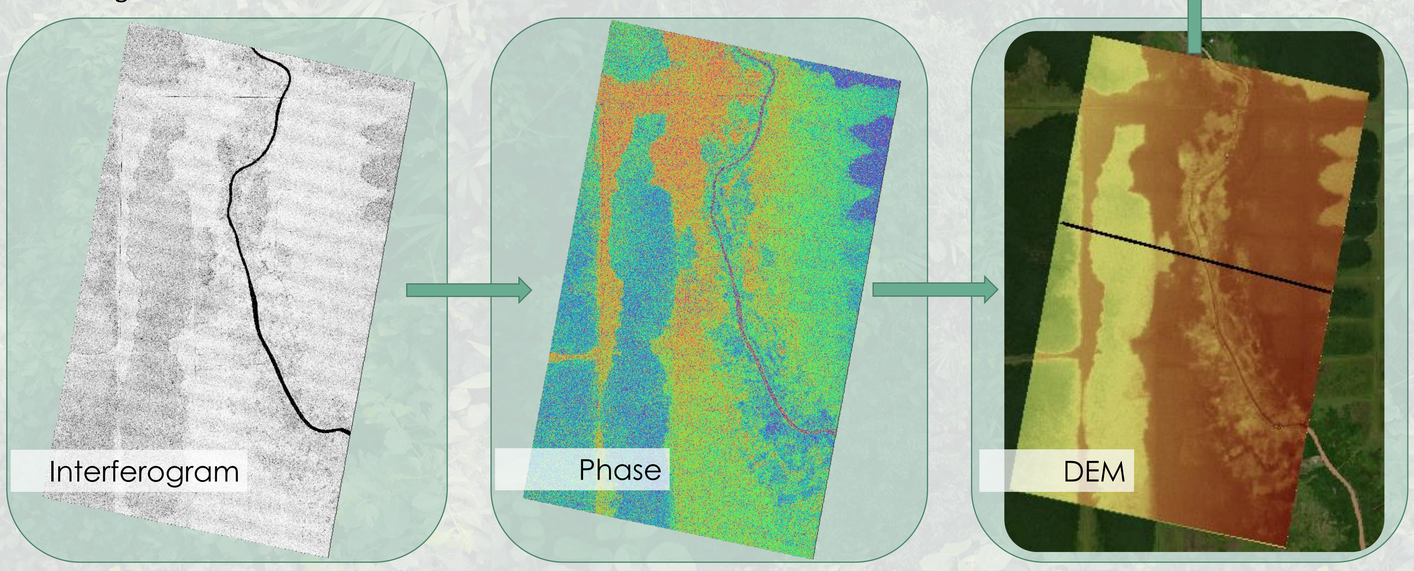


Table 1: DEM generation results of different sensors and acquisition parameters (++ very good, + good, - not good, -- bad)

Satellite	Date	Polarization	Baseline [m]	T. Baseline [d]	Inc. Angle [°]	Results
TS-X/TD-X	20101221	HH	163	0	46.8 - 48.5	++
TS-X/TD-X	20110825	HH+VV	92	0	29.5 - 31.3	++
TS-X/TD-X	20120110	HH+VV	36	0	47.4 - 48.4	+
TS-X/TD-X	20150811	VH+VV	1396	0	41.9 - 43.2	--
TS-X/TD-X	20150924	VH+VV	740	0	41.8 - 43.2	-
Sentinel-1	20150602-0626	VV+VH	57	24	39.2 (Mid)	--
Radarsat-2	20150819-1209	Quad-pol	114	24	31.2 - 36.6	--

Discussion and Conclusion

It can be shown that the spatial shift due to differing effective baselines together with too long temporal baselines introduce large errors during DEM generation. Due to continual changes in vegetation caused by processes such as wind, temporal shifts of even a few seconds were found to inhibit reliable DEM generation from Sentinel-1 and Radarsat-2 data in repeat pass mode with a temporal shift of 24 days (Lee et al. 2009).

TanDEM-X and TerraSAR-X CoSSC data are acquired within milliseconds of one another and were so found to produce more reliable DEM. But also some of the CoSSC data are influenced by to long effective baselines. An effective baseline longer than 300 m leads to corrupt results in the DEM generation. Even a to small baseline shows an increasing in the accuracy of the results.

Unfortunately the DEM differencing approach was not useful with the used sensors. The small wavelength (C-band and X-band) of the used sensors are influenced by even small branches and leaves and were not able to capture the ground information of the study area (Lee et al. 2009).

CH will be later translated to AGB with the use of a linear regression model and the potential of the presented synergistic approach to improve biomass estimation over tropical peat swamp forest will be discussed.

Due to the limitations of the SNAP environment it was unfortunately not possible to open quad-pol CoSSC data.

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