RELATING AMAZON FOREST BIOMASS TO POLINSAR EXTRACTED FEATURES

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ABSTRACT

The combination of polarimetric SAR (PolSAR) with the interferometry capability (InSAR) enables the extraction of new features that enhances the development of biomass estimation models. This work aims in demonstrating the importance of the simultaneous use of several types of SAR features for estimating forest biomass. The study site is São Gabriel da Cachoeira, located in the Brazilian Amazon. Forest inventory was conducted by INPA and a sample of 29 plots have been used to compute above and below-ground biomass. Polarimetric interferometric X and P band SAR data (PolInSAR) were acquired by the DSG's Amazon Radiography Project. After the initial analysis of the data and feature extraction, analyses on the relationship between biomass and SAR features have been done. Only 4 out of the 122 features extracted presented a significant correlation with biomass and each of them were related to a structural characteristic of the forest.

***Index Terms*—** forest biomass, Amazon, SAR, feature extraction

1. INTRODUCTION

The biomass estimation is intended to support ecosystems preservation plans in addition to provide information for sustainable forestry [1]. During the monitoring it also allows the verification of the type, direction, intensity and extent of degradation, in various areas, caused by human influence or natural causes as forest fires [2].

One way to estimate biomass in tropical forest regions is using remote sensing data, specifically those obtained by synthetic aperture radars (SAR) [3]. The combination of polarimetric SAR (PolSAR) with the interferometry capability (InSAR) enables the extraction of new features that can be used to estimate high biomass values without having saturation problems. Results obtained by [4] and [5] have shown that it is feasible the usage of such features in the Amazon region to estimate biomass values above 300 t/ha achieving coefficients of determination around 0.90.

In Brazil, the Terrestrial Cartography Subproject, also known as "Amazon Radiography", was designed by the Geographic Service of the Brazilian Army (DSG) for generating polarimetric interferometric SAR data (PolInSAR). It covers a total area of 1,142,000 km^2 of the Amazon region [6].

This project uses the OrbiSAR airborne sensors, which generates images in X and P bands with spatial resolution of 5m and enable the generation of new features that best represents the forest structural characteristics and biomass. Works of [2], [7] and [8] have shown that the usage of extracted features enhanced the biomass estimation models.

To model the relation between biomass and remote sensing data, forest inventories are also necessary. The quantification of biomass thought ground truth measurements are necessary since different allometric equations can be developed for different forest types [9].

The Carbon Dynamics of Amazon Forest Project (CADAF) aims at building a foundation on conserving the Amazon forest and is developing allometric equations for its different regions [10]. The National Institute for Amazon Research (INPA) and the National Institute for Space Research (INPE) are the brazilian governmental institutes responsible for its achievements.

This work aims in demonstrating the importance of the simultaneous use of several types of SAR features for estimating forest biomass, giving highlights for the polarimetric [11], interferometric [7] and texture [8] ones. This importance is validated by analysing the relationship between various extracted features and the arboreal forest biomass in a test site of the Brazilian Amazon.

2. MATERIALS AND METHODOLOGY

2.1. Study site

This case study focuses on the municipality of São Gabriel da Cachoeira (0°7'10 "S, 67°3'44" W), located on the upper Rio Negro basin in the northwest part of the Brazilian Amazon.

2.2. Data Acquisition

The forest inventory was conducted by INPA, as part of the CADAF Project, in the period between September and October of 2010. All inventoried plots have the same dimension (20 x 125m each) and belongs to the same forest type (primary *terra firme*). Inventories were performed using the same methodology (above and below-ground dendrometric measurements of trees with stem diameter at breast height superior to 10cm). Further details of the inventory can be found in [10]. From this inventory 29 plots were selected to compose the samples of this study. For each plot the total dry biomass value was calculated using the allometric equation given in [10]. The mass of dead trunks and fallen trees were also included in the inventory.

The PolInSAR data used in this work were obtained from the flight conducted in June 2009 from the Amazon Radiography Project and comprises the area between 67º and 68 ºW longitude and 0º and 01 ºS latitude. The following data were generated: orthorectified X (HH polarization) and P (full polarization) amplitude bands; digital terrain model (by interferometric P band); digital surface model (by interferometric X band) and interferometric coherence images.

2.3. Methodology

The methodology of this study involved the following steps: initial analysis of the data, feature extraction and the analyses on the relationship between biomass and polarimetric features. Each of these steps will be described below.

Initially all data from forest inventories and PolInSAR were qualitatively analyzed for possible noise, and compatibility inconsistencies. At this stage, it was assumed that because of all plots are of primary forest (*terra firme*), forest growth and, consequently, increased biomass between the date of the flight and inventory, was not significant.

The feature extraction based on PolSAR data was done directly on the original data [11]. The features extracted from the InSAR data were the interferometric height, by computing the height difference between the surface and the digital terrain models [7] for each pixel, and the terrain slope, using the digital terrain model. Several texture features were extracted from the amplitude orthoimages, using co-occurrence matrices with different window sizes [8]. At the end of the feature extraction step 122 features were derived to be analyzed.

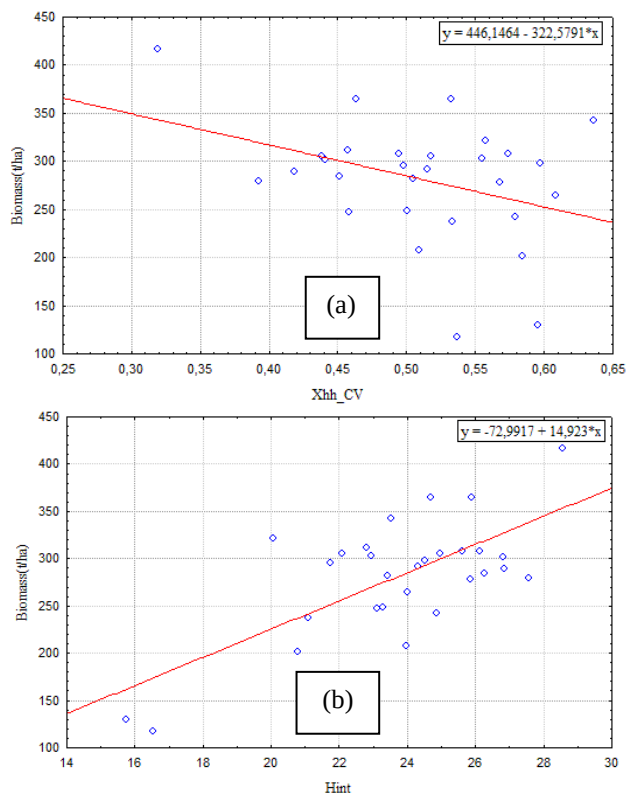
The relation between the forest biomass and the polarimetric features was made associating the biomass of the 29 plots inventoried and the georreferenced SAR data extracted features. Each plot corresponds to approximately 100 pixels in the image of which the arithmetic mean was computed.

The selection of the most important features was performed by analyzing the correlation between each feature (or its functions) and forest biomass values. The Pearson correlation (r) was used and the features selected for analyzing their relation with biomass were those that had statistically significant correlation at 95% confidence level.

3. RESULTS AND DISCUSSION

Despite all the 29 plots were from primary forest inventories, there was a wide range of total biomass values ranging between 118 and 417 t/ha, with an average of 281 t/ha and standard deviation of 63 t/ha. Within each plot, between 98 and 152 individual trees were inventoried, with an average of 124 individuals and a standard deviation of 16.

Only 4 out of the 122 features extracted presented a significant correlation with biomass: coefficient of variation of the X-hh band (Xhh_CV), interferometric height (Hint), interferometric coherence of the X-hh band (Xhh_Coh) and the Haralick´s second moment texture of the P-hv band, obtained with 3x3 window size (Phv_Se). The correlation of each of these bands with biomass, and their corresponding p-values (in parenthesis) were, respectively, -0.37 (0.049), 0.70 (<0.000), -0.39 (0.036) and -0.52 (0.003).



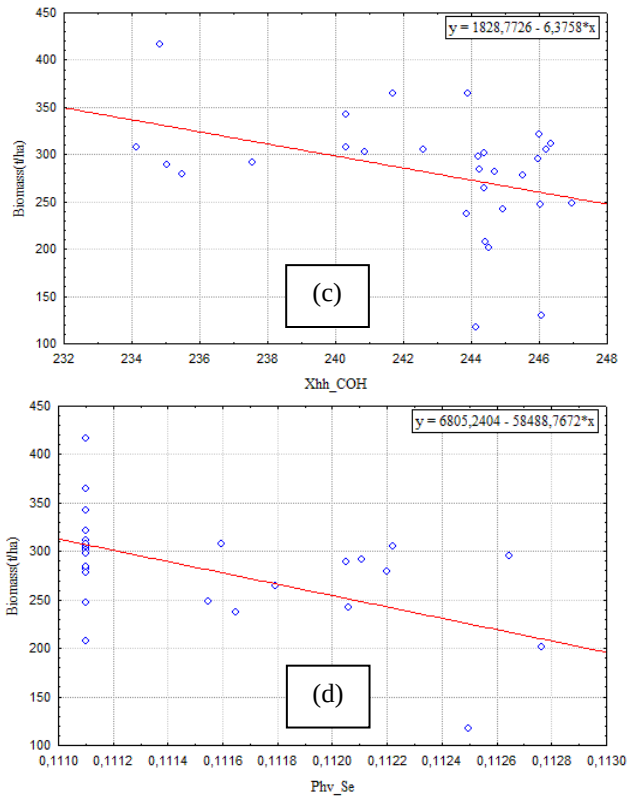


Figure 1 - Scatter plots of the correlation between biomass and PolInSAR features of (a) Xhh_CV, (b) Hint, (c) Xhh_Coh and (d) Phv_Se.

Figure 1 presents the scatter plots of the correlated features with biomass. The Hint presented the highest correlation with biomass. This fact, also observed by other authors [4] [5] [7], was expected since interferometric height estimates the height of the trees and therefore has a strong relationship with arboreal biomass. The Xhh_CV and Xhh_Coh features obtained the lowest correlation coefficients. These features are related to the canopy forest volume and, consequently, to its biomass. The Phv_Se feature, although presenting a median correlation coefficient (r = -0.52), seems to saturate as biomass increases. It's related to the volume backscattering of the trees steam and branches which are associated with the trunks biomass.

The Xhh_CV, Xhh_Coh and Phv_Se features are negatively related to biomass. This occurs by the fact that it represents the variability of the backscatter, which can be related to shadows and canopy openness.

4. CONCLUSION

The analyses of different types of extracted PolInSAR features are essential for understanding the forest structure. Some features appear to be mostly correlated to the tree steam while others are associated to the canopy volume. Thought the combination of different features related to distinct parts of the tree, the modeling of the arboreal biomass seems feasible.

Together with the feature extracted directly from the original PolInSAR data, other features can be derived using decomposition methods including Krogager, Huynen, H/A/α, Freeman, Touzi, Barness and Holm. In this case, polarimetric single-look complex images must be available to be processed. The analysis of decomposition methods features together with the construction of biomass estimation models and its respective maps, consists of the next steps of our research.

5. REFERENCES

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