ESTIMATING HISTORICAL FOREST ABOVEGROUND BIOMASS IN NORTHERN BORNEO USING SRTMGL1 AND AIRBORNE LIDAR DATA

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Abstract: Monitoring forest carbon stocks is challenging in the tropics due to a lack of historical data on aboveground biomass (AGB). We examined the use of NASA SRTM Version 3.0 Global 1 arc second dataset (SRTMGL1) to estimate tropical forest AGB in Northern Borneo. Field AGB was calculated using tree diameter at breast height, tree height species information. A 1m-digital terrain model was generated from Light Detection and Ranging (LiDAR) data. Datum transformation was carried out to match the vertical datum of SRTMGL1 and LiDAR dataset. The remote sensing datasets were resampled to 1m, 5m, 10m and 30m resolutions. Both LiDAR DSM and SRTMGL1 were subtracted with the LiDAR DTM to generate a Canopy Height Model (CHM). SRTM CHM was calibrated using the LiDAR CHM for different resolution. Regression analyses showed that the 1m resolution LiDAR CHM mean was the best resolution to estimate AGB (R^2 = 0.757; relative root mean square error = 27.18%). The model was applied to the calibrated SRTM CHM to estimate the historical AGB in the tropical forest.

Keyword: (SRTM, LiDAR, Carbon stock, tropical forest, Sabah)

Introduction

Tropical forests play a critical role in climate change mitigation, but anthropogenic land use activities are causing the role of these forests to change from carbon sink to source. It is crucial to monitor the forest aboveground biomass (AGB) of tropical forests to understand its role as carbon sink or source. Historical AGB estimates of these forests can provide crucial baseline data of the AGB. However, field data that are necessary for historical AGB calculations, are seriously lacking in the tropics (Maycock et al., 2019).

Remotely sensed digital elevation data, such as Light Detection and Ranging (LiDAR) and Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), correlate well with forest canopy height (Sexton et al., 2009). The SRTM data shows great potential in AGB estimation (Lagomasino et al., 2016; Phua et al., 2020). Recently, SRTM DEM data has been improved and released as NASA SRTM DEM. We examined forest AGB estimation using the NASA SRTM DEM. Specifically, our objectives were to examine the correlation between the canopy height information in SRTM data and LiDAR canopy height model (CHM) for developing an SRTM-to-LiDAR canopy height calibration model and to determine the best spatial resolution for developing an AGB estimation model using field and LiDAR data that can be applied to the SRTM canopy height values.

Materials and Methods

Airborne LiDAR data were acquired in 2012 using Riegl LMS-Q560. We used the TerraScan software to classify the point clouds as ground and vegetation points. The ground points were interpolated to a grid with 1 m spacing as A digital terrain model (DTM) and digital surface model (DSM) at 1 m pixel resolution were generated using the ground and vegetation points, respectively. The LiDAR DSM and DTM models were resampled to 5, 10, and 30 m spatial resolutions using the nearest neighbor resampling method. A LiDAR canopy height model (LiDAR CHM) was calculated by subtracting the LiDAR DSM from the LiDAR DTM for each resolution. The vertical datum of LiDAR data was converted from WGS84 ellipsoid to Earth Gravitational Model (EGM96) geoid to match the vertical datum of SRTM DSM (Simard et al., 2006) using the ArcGIS Data Management Tools.

The SRTMGL1, also known as NASA SRTM DEM data, is the SRTM version 3 dataset (Resolution: 30 m). The data were downloaded from USGS's Earth Explorer website (http://earthexplorer.usgs.gov/). Since interferometric SAR signals transmitted from SRTM have a weak penetration rate, the DEM elevation values of vegetation areas likely represent the canopy level or a digital surface model (DSM). Both LiDAR and SRTM DSM data at 1, 5, and 10 m pixel resolutions. We focused on using the LiDAR CHM to calibrate the SRTM data's canopy height values. The LiDAR DTM was subtracted from the SRTM DEM to create a CHM for SRTM (SRTM CHM). For linear regression analysis, we used the LiDAR CHM data from old-growth forest plots to produce an equation to calibrate the SRTM CHM values. To ensure that no disturbance operations had taken place before our investigation, the old-growth forest plots were checked in the field and with the local villagers.

Results and Discussion

In this study, we examined the LiDAR-CHM mean as the predictor of field AGB for different spatial resolutions. Table 1 shows the calibration equations of SRTM CHM for all resolutions. All calibration models had fair to strong goodness-of-fit values (R^2 = 0.758 - 0.828) except for 30 m resolution (R^2 = 0.418). The regression analyses showed that the field AGB could be estimated with LiDAR CHM mean as the predictor for all spatial resolutions except 30 m, which had a very low R^2 (Table 2). Overall, the model with LiDAR CHM mean at 1 m resolution predicted the field AGB with the lowest RMSE value at 77.59 Mg/ha (Relative RMSE = 27.18%). Leave-one-out cross-validation (LOOCV) method was used for the validation of the best model of 2012. The LOOCV showed that the best model has RMSE value of 81.10 (Relative $RMSE_{LOOCV}$ = 28.41%) in (Figure 1). Similar to Loh et al. (2020), the 1 m resolution LiDAR CHM had the best fit and explained the AGB variance better than other spatial resolutions in the regression analysis. When the pixel size increases or spatial resolution decreases, the small forest canopy gaps could be overlooked, leading to an overestimation of the forest canopy height (Mascaró et al., 2011). By applying the best model to the SRTM CHM, the historical AGB in 2000 can be estimated (Loh et al., 2020).

Conclusion

Historical aboveground biomass (AGB) data is crucial in monitoring AGB changes in tropical forests. We examine the use of very high-resolution airborne LiDAR data to calibrate the moderate-resolution NASA SRTM DEM to estimate the historical AGB. The calibration worked best for high spatial resolutions i.e. 1 m and 5 m. The AGB estimation model was developed using the LiDAR data. The AGB estimation model using 1 m-LiDAR CHM was superior to the models of lower resolutions. This calibration and modeling approach can be applied in other regions to estimate the historical AGB.

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Table 1. SRTM CHM calibration models using old-growth forest plots (n= 18)

Resolution	Model	R^2
1m	$SRTM\ CHM_{CAL}$ = 0.837(SRTM CHM) + 3.4134	0.828
5m	$SRTM\ CHM_{CAL}$ = 0.8503(SRTM CHM) + 2.7147	0.828
10m	$SRTM\ CHM_{CAL}$ = 0.8193(SRTM CHM) + 3.8834	0.758
30m	$SRTM\ CHM_{CAL}$ = 0.9077(SRTM CHM) + 3.0192	0.418

Table 2. Aboveground biomass (AGB) estimation models using LiDAR CHM (n = 74)

Resolution	Model	R^2	$RMSE_{model}$ (Mg/ha)	Relative $RMSE_{model}$ (%)
1m	Ln(AGB)= 2.372(Ln(CHMmean 1m)) - 1.929	0.757	77.59	27.18
5m	Ln(AGB)= 1.261(Ln(CHMmean 1m)) +1.618	0.404	95.11	33.31
10m	Ln(AGB)= 0.584(Ln(CHMmean 1m)) +3.756	0.207	118.12	41.37
30m	Ln(AGB)= 0.4863(Ln(CHMmean 1m)) + 4.0174	0.181	121.12	42.43

Figure 1. Scatterplot between field AGB and estimated AGB using 1 m-LiDAR CHM