IOP Conference Series: Earth and Environmental Science

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To cite this article: S Misbari and M Hashim 2014 *IOP Conf. Ser.: Earth Environ. Sci.* **18** 012144

IOP Conf. Series: Earth and Environmental Science **18** (2014) 012144 doi:10.1088/1755-1315/18/1/012144

Total aboveground biomass (TAGB) estimation using IFSAR: speckle noise effect on TAGB in tropical forest

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Abstract. Total Aboveground Biomass (TAGB) estimation is critically important to enhance understanding of dynamics of carbon fluxes between atmosphere and terrestrial ecosystem. For humid tropical forest, it is a challenging task for researchers due to complex canopy structure and predominant cloud cover. Optical sensors are only able to sense canopy crown. In contrast, radar technology is able to sense sub-canopy structure of the forest with penetration ability through the cloud for precise biomass estimation with validation from field data including diameter at breast height (DBH) of trees. This study is concerned about estimation of TAGB through the utilization of Interferometry Synthetic Aperture Radar (IFSAR). Based on this study, it is found that the stand parameters such as DBH and backscattered on IFSAR image has high correlation, R2=0.6411. The most suitable model for TAGB estimation on IFSAR is Chave Model with R2=0.9139. This study analyzes the impact brought by speckle noises on IFSAR image. It is found that filtering process has improves TAGB estimation about +30% using several filtering schemes especially Gamma filter for 11x11 window size. Using field data obtained from a primary tropical forest at Gerik, Perak, TAGBestimation can be validated and the assessment has been carried out.

1. Introduction

Forest is the main source of biomass, carbon and home of many species of flora and faunas. It plays vital role in protecting the sustainability of the Earth's ecosystem. Malaysia is a tropical country where the forest covers almost 60% of the land, equal to 19.52 Mha^{-1} where 3.21 Mha^{-1} of overall forestry area is strictly preserved as the primary forest [1]. TAGBusing conventional technique is inefficient as the measurement of DBH and other tree stand parameters are not practicable over the large region of dense forest which in turn causes time-constraint and ineffective cost.

The backscatter of IFSARis one of essential element of TAGB estimation in tropical forest. Therefore, it is the prominent objective of this research where extensive potential of IFSAR in TAGB estimation was applied. The specialty of this study is obviously penetrated into the discovery of knowledge tunnel in revealing the airborne SAR in TAGB prediction for tropical climate forest which is highly dense with several crown canopy levels of forest trees. Previous study have been conducted in Pasoh Reserved Forest in Negeri Sembilan, Malaysia using optical satellite image of IKONOS, Landsat and Moderate Image Spectrometer(MODIS) to estimate TAGB using allometric model where the range of TAGB is from 0.3tha^{-1} to 15tha^{-1}foreach plot of 4m x 4m on IKONOS [2].

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2. Data and material

The study area is located at Gerik in Perak state, northern part of Peninsular Malaysia. During field dataacquisition, several parameters are recorded such as DBH, scientific and local name of the tree, x and y coordinate, plot number and line number. Using IFSAR scene of this area as primary data, it was projected in Rectified Skew Orthomorphic (RSO) and Kertau 1948 as its datum. With north latitude of 5^0 33’ 25.68”N and east longitude of 101^0 38’29.41” E, this area is about 230km from the Ipoh town and 430.5km from Kuala Lumpur. The IFSAR scene is about 50.0884km^2 or 5008.84ha but only 198ha involved in this research. The area is almost fully covered by forestry area and dominated by the species of Meranti and Keruing trees as recorded by the Forest Department of Perak Officer in 2010.Overall, 31 square plots of 80 pixels x 80 pixels were selected.

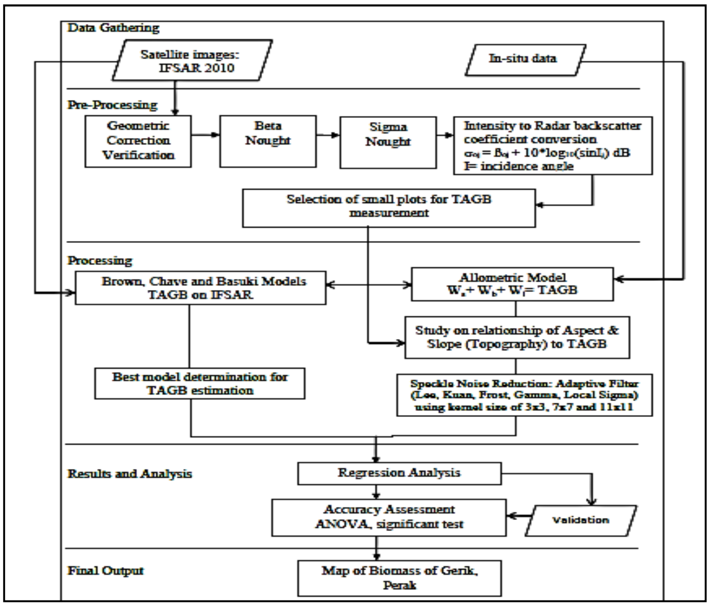

Figure 1. The flowchart diagram of TAGB estimation.

In processing stage, using DBH data from ground work, the measurement of biomass of tree structure are computed in order to obtain TAGB using allometric equation by Kato, 1978.

$$\frac{1}{H} = \frac{1}{(1.5D)} + \frac{1}{61} \quad \text{[Tree height]} \quad (1)$$

$$W_s = 0.0313\ (D^2H)^{0.9733} \quad \text{[Biomass on the tree's stem]} \quad (2)$$

$$W_b = 0.039\ (D^2H)^{1.041} \quad \text{[Biomass on the tree's branch]} \quad (3)$$

$$\frac{1}{Wl} = \frac{1}{(0.124Ws^{0.794})} + \frac{1}{125} \quad \text{[Biomass on the tree's leaves]} \quad (4)$$

Finally, $TAGB = W_s + W_b + W_l$ (5)

whereH = tree’s height,D = DBH, TAGB = Total Aboveground Biomass.

For TAGB extracted from IFSAR, three models are selected:
Brown Model (1997), Y = exp [-2.134 + 2.530*ln (d)],
Chave Model (2005), Y = ρ x exp (-1.499 + 2.148 ln (d) + 0.207 (ln (d)) 2 – 0.081 (ln (d))*3),
Basuki Model (2009), Y = exp (-1.201+2.196*ln (d)).
whered=DBH, ρ=specific wood density, 0.67g/cm.

Speckle noise image were minimized using several adaptive filter with widow size of 3x3, 7x7 and 11x11. Variation coefficient (CV) and Signal-to-Noise (SNR) of resultant images were tabulated. After determine the best filter, the result of TAGB before and after filtering process were compared and analyzed to see the impact of filtering speckle noise on IFSAR. Finally, the TAGB on different range of slopes and aspects of topographic variation on this area were explored and analyzed.

3. Result

3.1. Relationship of tree parameters and backscattered of IFSAR to determine the best modelfor TAGB estimation onIFSAR

The result of several tasks was displayed below.

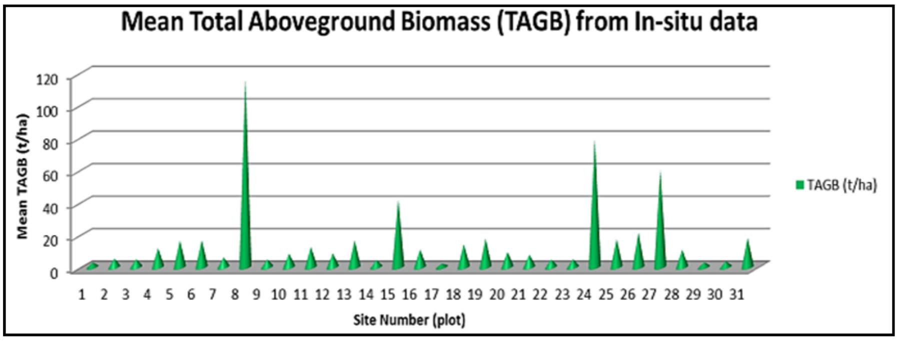

Figure 2. Mean TAGB of every selected plot by allometric model.

Table 1. Range of DBH value from backscattered obtain from IFSAR.

Backscattered IFSAR (decibel, DB)	DBH (cm)	TAGB (t/ha)
-20 to -10	30-55	>2.3to <8.3
-10 to -5	56-70	>8.3 to <11.9
-5 to3	71-90	>11.9 to <30.8
3 to 7	91-170	<135

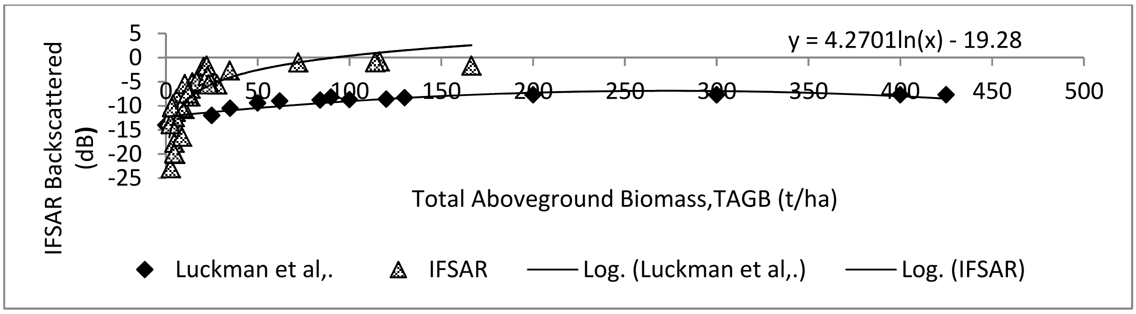

Figure 3. Comparison of TAGB and its backscattered value on tropical forest region by Luckman *et al.*, within moderately flat Amazon Forest (saturation at -7.7dB) and IFSAR at hilly forest at Gerik, Perak (saturation at -1.7dB).

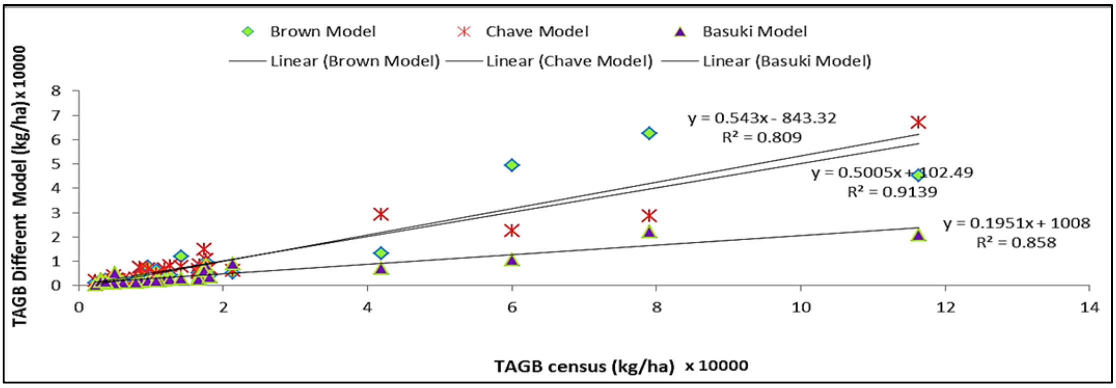

Figure 4. Different model of TAGB estimation shows different regression coefficient. Chave model line shows highest correlation compared to tohers.

3.2. Speckle noise filtering effect on TAGB

As Chave model was determined as the best to be used for TAGB estimation on IFSAR image, the biomass map of tropical forest at Gerik Malaysia was then is tested using several adaptive filters and the statistical result was tabulated in the table below.

Table 2 Summary of information obtained from post-filtered IFSAR image.

Filter	Window size	Mean	Std. Dev	Variation Coefficent (VC)	Signal-to-Noise Ratio (SNR)
Original		63.054822	52.154227	0.827125117	1.209006932
Lee	3x3	62.958742	50.558324	0.803038981	1.245269562
	7x7	62.866357	48.385716	0.769659931	1.299275121
	11x11	62.808903	47.117486	0.750172089	1.333027467
Frost	3x3	62.519443	49.361000	0.789530387	1.266575697
	7x7	62.174246	45.847429	0.737402252	1.356111943
	11x11	61.774875	43.808126	0.709157663	1.410123661
Local Sigma	3x3	62.710177	51.931134	0.828113338	1.207564175
	7x7	62.383293	50.706329	0.812819051	1.230286125
	11x11	62.270527	50.329257	0.808235604	1.23726299
Kuan	3x3	63.023406	49.626327	0.787426928	1.269959109
	7x7	63.187646	47.546164	0.752459808	1.328974636
	11x11	63.158963	45.785997	0.724932691	1.379438412
Gamma	3x3	63.033169	49.393649	0.783613608	1.276139145
	7x7	63.025534	45.599395	0.723506682	1.382157241
	11x11	63.023184	43.004939	0.682366968	1.465487115

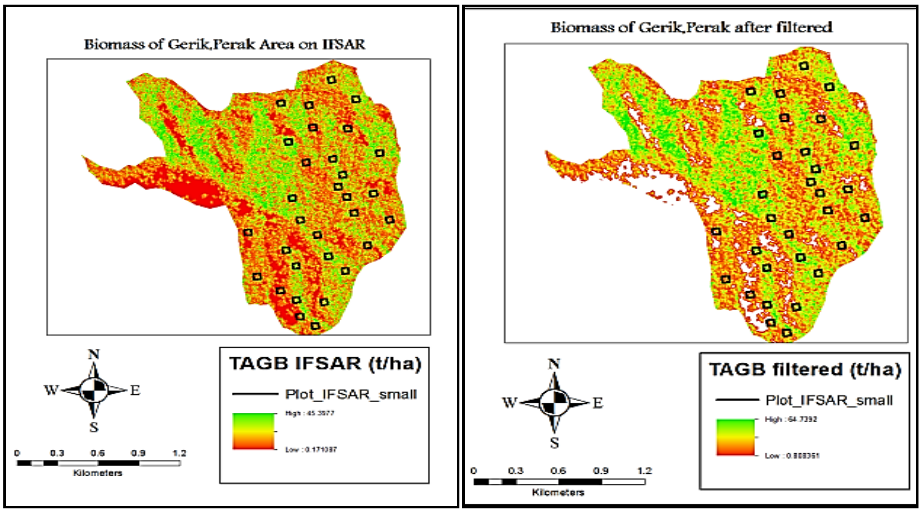

Figure 5. TAGB map before and after filtering process on IFSAR.

4. Analysis and discussion

Based on Figure 2, minimum TAGB is 1886.166kg/ha at plot 17^{th} and the maximumTAGB among selected trees is 116363.787 kg/ha at plot 8^{th}. Through this graph, it was concluded that TAGB of this tropical forest was mostly less than 20kg per hectare. Large DBH indicates that the trees can live longer at that area compare to the other plot but it is rarely found because of natural competition to obtain basic elements to grow like sunlight and its natural life-span. Table below shows the characteristics of trees at plot number 8 and 17.

Figure 4 shows that mean backscatter value of IFSAR for each plot with mixed species is positively correlated with TAGB estimated by allometric model with R^2= 0.6411. The equation $Y=19.062e^{0.124x}$ then applied on IFSAR to estimate TAGB for further task.

Table 3. Summary of statistical information for different TAGB models.

Allometric Model (Kato *et al.)*	R^2 *(correlation coefficient)*	RMSE	CV (%)	*p*-value
Brown Model (1997)	0.809	0.484	14.5	1.56E-11
Chave Model (2005)	0.9139	0.370	8.7	2.29E-16
Basuki Model (2009)	0.858	0.417	11.3	1.94E-13

Null hypothesis for this task is the mean value of TAGB from census data and Chave models are the same, no different significantly. However, based on ANOVA table, $F_{critical}<F_{computed}$indicating that the null hypothesis is rejected at 95% confident level. It means that mean value of TAGB estimated from Chave model was significantly different with mean TAGB derived from ground data at high significance difference,2.29E-16.

For speckle noise effect, different filter will give us different image in terms of their clarity and level ratio of signal to noise. VC represents variability extension with respect to mean of the population. Regarding to Table 2, it shows that smaller the variation coefficient, smaller the effects of speckle noise on the image. Standard deviation of all resultant figures is not broadly ranged due to speckle noises sources located on vegetation features area, a dominant feature of this area which in turn leads to small range of VC value. As VC is the inverse of SNR, lowest VC is the highest SNR value. The lowest VC where shown by Gamma 11x11 filter by 0.6824 is containing more signal rather than speckle noise on image with SNR value of 1.4655.

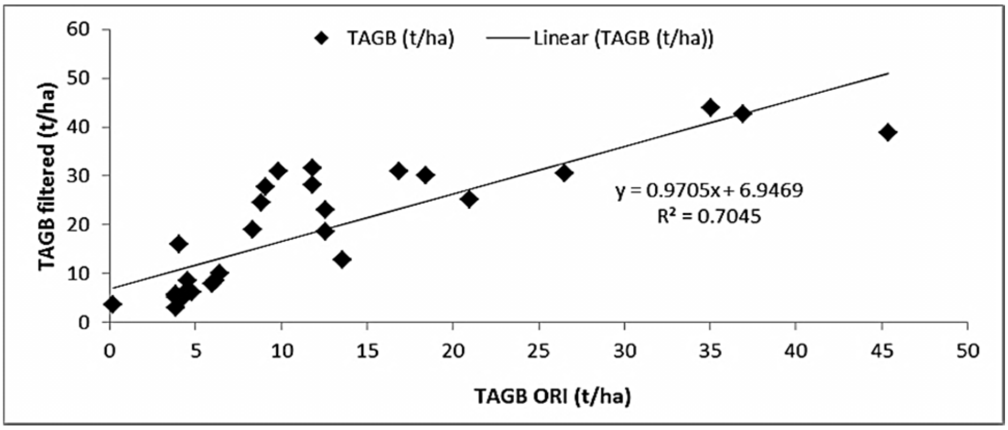

Figure 6. Regression line of TAGB of 24 plots before and after speckle noise reduction. It demonstrated that TAGB estimated was improved by +30%.

Null hypothesis for this task is the mean value of both TAGB before and after speckle noise reduction by filtering process using adaptive filter was no difference. For this, $F_{critical} < F_{computed}$ indicates that the null hypothesis is rejected at 95% confident level. It means that mean value of TAGB on raw IFSAR is significantly different with mean TAGB extracted from IFSAR after speckle noise filtering by Gamma 11x11 kernel size at P=0.0161.

5. Conclusion

To put it to the nutshell, TAGB can be predicted using IFSAR backscatter with 64.11% is true based on its correlation.The most suitable model to estimate TAGB on IFSAR is Chave Model with R^2=0.9134, P<0.0003 and the standard error is 1.981 t/ha.The reduction of speckle noise through filtering process has improves TAGB estimation to +30%.

Acknowledgement

This research was supported by a research grant under Ministry of Higher Education (MOHE), UniversitiTeknologi Malaysia, Skudai campus to the Institute of Geospatial Science and Technology (InsTeG) using Q.J130000.2509.05H12-Modeling Spatial and Temporal Methane Emission from Wetlands and Converted Wetland-to-Oil Palm Plantation Using Satellite Remote Sensing Data.

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