International Journal of Integrated Engineering, Vol. 10 No. 4 (2018) p. 140-150
© Penerbit UTHM
DOI: https://doi.org/10.30880/ijie.2018.10.04.023

Upscaling Aboveground Biomass Estimation at Low-land Royal Belum Forest Reserve Using Unmanned Aerial Vehicle Image

Abd Wahid Rasib[1], Hamzah Mohd Ali[1], L.M.S. Alvin[1], K.D. Kanniah[1], Nurul Hawani Idris[1], Hamdan Omar[2], Azahari Faidi[2], Rozilawati Dollah[3], and Mustaffa Anjang Ahmad[4*]

[1]Tropical Map Research Group, Faculty of Built Environment and Surveying, UTM, 81310, Skudai, Malaysia.
[2]Forest Research University Malaysia, 52109 Kepong, Selangor, Malaysia
[3]School of Computing Universiti Teknologi Malaysia, 81310, Skudai, Malaysia
[4] Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Batu Pahat, Malaysia

Received 13 December 2017; accepted 2 October 2018, available online 24 October 2018

Abstract: Thermal properties of certain building materials were studied with respect to environmental aspects. The building materials with significant insulation properties were laboratory tested using the special equipment based on Peltier module. During the experimental work, the samples of the following materials were tested: Expanded polystyrene (EPS), Autoclaved aerated concrete (AAC): Ytong, Calcium Silicate Board: Super-Isol and Foam glass (Cellular Glass Insulation): PERINSUL. The temperature was measured directly in connection of material with the Peltier module as well as in the distances of 5mm, 27.5mm, 50mm and 95mm from the Peltier module. The temperature taken at the surface of Peltier module reached -22°C, a typical temperature in the cold winter season. The results of the laboratory experimental work were modelled using the graphic representation. Modelling the thermal distribution will help to determine the ideal material thickness in the design of the building insulation.

Keywords: Analysis; building materials; environment; optimization; thermal properties

1. Introduction

Generally, tropical rainforests cover approximately six percent of earth total surface area. Meanwhile, the tropical rainforests region is located between the tropic of capricorn and cancer in the south and north respectively. Due to the constant amount of sunlight exposure as well energy from the sun, these tropics provide a suitable climate condition for tropical rainforest. Most of tropical rainforest coverage are situated mainly at continent of Africa, continent of America and continent of Asia respectively. The tropical rainforests in Africa approximately covered around 184-200 million hectares. While, America covered area around 520 million hectares and Asia area approximately around 240-260 million hectares [1]. There is various type of tropical rainforest such as montane rainforest, monsoon rainforest heath rainforest and more [2]. The majority of tropical rainforest is lowland tropical rainforest, forest which grows on flat land. For this study it focused on lowland tropical rainforest.

Lowland tropical rainforest can be characterized into three different type layer of tree canopies which are upper layer, second layer and lower layer respectively. The upper layer is located between 30 to 40 m and sometimes can reach 60 m. The second layer is located between 23 to 30 m and the lower layer consists of several types of vegetation mainly herbs and small tree [2]. Tropical rainforest consists of various types of tree species such as Hopeacoriacea Burck (GiamHantu), Dipterocarpusfagineus (Meranti), Shoreabentongensis [4] and more than 1000 tree species per square kilometer. Furthermore, there also contains the tallest tree among all types of rainforest [3]. Besides that, Lowland tropical rainforest also can be characterized based on terrestrial elevation and the environment condition.

The overall terrestrial elevation of lowland tropical rainforest is below than 700 m from mean sea level (MSL) then above than that will be classified as montane rainforest. For Malaysia, lowland tropical rainforest is hill based dipterocarp forest that is normally found in 500-700m above sea level [4]. For temperature in lowland tropical rainforest, the average temperature for lowland tropical rainforest is 21-29 Celsius that causes by the product of high temperature and abundant amount of rainfall which is a suitable environment for vegetation growth. Based on the characteristic, Malaysia has numerous lowland tropical rainforest such as Royal Belum Forest Reserve, Kanching Forest Reserve and Sepilok Forest Reserve.

*Corresponding author: mustafa@uthm.edu.my

This study is conducted at one of the oldest tropical rainforests, Royal Belum Forest Reserve and believed exists about 130 million years ago. Royal Belum Forest Reserve is classified as the largest primary forest existed in Peninsular Malaysia and it rich in flora and fauna. In addition, Royal Belum Forest Reserve also has a high concentration of tropical rainforest tree species. Thus, report regarding aboveground biomass is an essential for monitoring carbon stock at Royal Belum Reserve Forest.

Aboveground biomass estimation is importance, various method and tool have emerged to assist the estimation and the most trending method is upscaling. Upscaling also known as aggregation which is a process of scaling up spatial data [5]. The upscaling method can be described as an adequate method that can be used to estimate the aboveground biomass for the whole area of forest.

The usage of upscaling method is more practical compared to an ordinary traditional that uses regular tree census at experimental plot. Traditional method consumed a lot amount of resources, time, and show the inaccurate area of aboveground biomass estimation. Therefore, upscaling method is more practical and the usage of this method can effortlessly help the forest community to spatially estimate the aboveground biomass for high density and large area of forest. Furthermore, biomass estimation is an essential parameter in monitoring carbon stock which related to UN-REDD programmed.

UN-REDD programed or known as United Nations Programmed on reducing emissions from deforestation and forest degradation is a framework to monitor forest activities especially carbon stocks. The goal of this programmed is to reduce forest emission and enhance carbon stocks in forests while contributing to national sustainable development [6]. Hence, to support UN-REDD programmed this study propose a potential method that might suitable in monitoring aboveground biomass for forest community.

The aims of this study is to produce the upscaling biomass map for Sungai Papan at the coverage of 22 hectares located in Royal Belum Forest Reserve, Perak. Mainly this study is intended to investigate the potential low cost multispectral image based on the unmanned aerial vehicle (UAV) platform in estimating aboveground biomass using upscale correlation method. The result from this study suppose able to be benefited in the enforcement of UN-REDD programmed in providing real-time information of forest condition especially in high density tropical rainforest such as Royal Belum Forest Reserve.

2. Methodology

The execution of methodology for this study is divided into five phases, which are data acquisition, data preprocessing, data processing, data analysis and lastly results. Each phases contain a description of those activities that will be conducted. The first phase is data acquisition which multispectral images were acquired by using two compact sensors that mounted on UAV. The flight path of the UAV is based on designated flight planning. At the meantime, ground measurement been conducted concurrently involved establishment experimental plot at 100 m x 100 m, the tree census of DBH (diameter at breast height), tree location marking and recorded as well as establishment of ground control point. The second phase is data pre-processing, UAV image that acquired will go through layer stacking and stitching process in order to produce and orthophoto. Subsequently, the orthophoto image will geometric corrected based on local Rectified Skewed Orthomorphic coordinate system (RSO).

The third phase is the main processing in this study whereby involved the biomass estimation using tropical allometric equation and derivation of eight vegetation indexes using UAV multispectral images (RGB and NIR). While, the fourth phase is data analysis which implementing the regression model to obtain the correlation between aboveground biomass and vegetation indices. Then, an accuracy analysis is conducted using RMSE (Root Mean Square Error) and t-test. The final product of this study is a map shows the upscaling of biomass concentration for 22 hectares of Sungai Papan, Royal Belum Forest Reserve.

2.1 Study area

The study was carried out at Royal Belum Forest Reserve, located in the Gerik, Perak, area (Hulu Perak) also known as the Royal Belum State Park (RBSP). The study area is located at Sungai Papan of Royal Belum Forest, latitude 5º36’18.76’’, longitude 101º25’8.64’’. According to World Wide Foundation (WWF), Malaysia stated that The Royal Belum Forest Reserve was legally gazetted by the Malaysian government as a protected forest covering 117,500 hectares in 2007 and it is managed by the Perak State Parks Corporation [7]. RBSP is bordered by Thailand in the north, in the east is the state of Kelantan, and in the west is Sungai Gadong for the southern border will be the East-West Highway [8]. The study site is illustrated in Fig.1.

Three type of forests that can be found in Royal Belum Forest Reserve which lowland dipterocarp, hill dipterocarp and upper dipterocarp forests where extending from 260 m to 1,533m from mean sea level [7]. Generally, this tropical rainforest has a high humidity of 70 to 90 percent that caused by the abundant rainfall and consistently high temperature [1]. As located in tropical climate, Royal Belum has a temperature between 23 °C to 32 °C, and rainfall ranging from 10 centimeters to 30 centimeters a month. In addition, Royal Belum Forest Reserve is located at North, between East and West coast of Peninsula. Hence, it tends to be drier between December and April because of the northeast monsoon. The tree species that grow in this forest is mainly from Dipterocarpaceae family and it also become a habitat for various type of animal species such as Asian elephant, Malayan tiger and Sumatran rhinoceros.

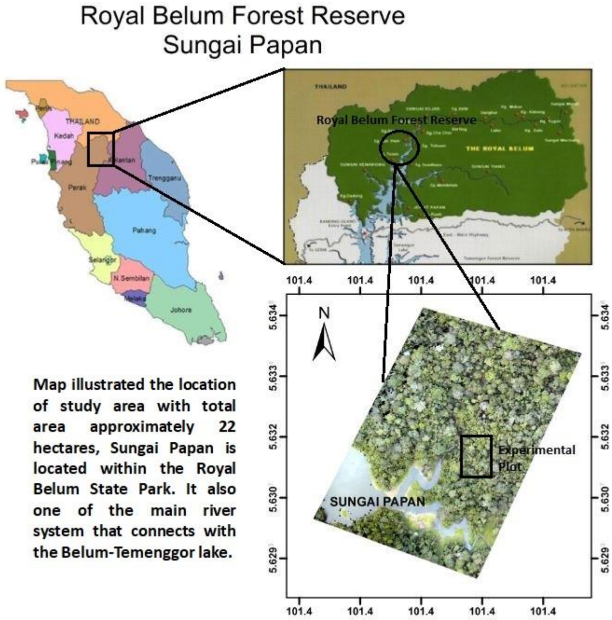
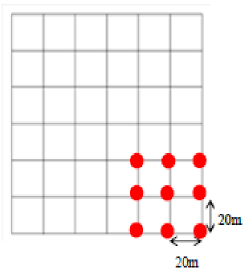


Fig. 1 Location of study area

2.2 Design of experimental plot

In this study 100m × 100m size experimental plot was created to observe the ground point on each intersection between x and y axes. After that, by using setting out survey, 20m × 20m quadrant were created as shown in Fig. 2. The quadrant will be marked by 1m long pipe of PVC that sank 0.8m in the ground. Only single experimental plot with size area about 1 hectare successfully been established due to the cost and time consuming. Subsequently, square plot design sampling was chosen and used to facilitate pixel sampling on UAV imagery that reduce the position error caused by Global Positioning System (GPS) observation and make the orientation shape is similar to the shape of the UAV image pixel. Based on [10] stated that the use of remote sensing products and techniques such as air-photograph proved to be very useful when backed up by quadrant sampling measurement on the ground.



	X	Y
UL	379162.963	623130.597
LR	379253.597	623022.036
MRSO Coordinate System		

Fig. 2 Experimental plot 100 m x 100 m grid

2.3 Primary data

The UAV flight was organized on the 3rd November 2015 at Royal Belum Reserve Forest, Perak. In this study, the aerial images were taken by using UAV Phantom 4 equipped with MAPIR sensor, dimensions of 4032 × 3024 pixels as shown in Fig. 3 and Fig. 4, respectively. Data acquisition using UAV can be consider as low-cost platform image but able to provide high spatial resolution and fee cloud image. There are two set of images that provide from UAV flight which are red, green and blue band (RGB) images as shown in Fig. 5 and also Near Infrared (NIR) images as shown in Fig.6. A total of 422 photo images were taken at an altitude of 546 meters where 186 images were RGB band and 236 images were NIR. The differences amount of images between RGB and NIR that occurred because of the images were taken separately. Table 1 shows the specification of both MAPIR sensor.


Fig. 3 UAV DJI Phantom 4.

Fig. 4 MAPIR Sensor.


Fig. 5 Unmanned Aerial Vehicle Image with RGB composite using MAPIR sensor.

Fig. 6 Unmanned Aerial Vehicle NIR Image using MAPIR sensor.

Table 1 General specification of MAPIR sensor for composite band RGB and NIR

Image Resolution	16 Mega Pixel (4,608 x 3,456 px), 12MP, 8MP, 5MP, 3MP
Image Format	RAW+JPG, JPG - 24bits RGB
Video Resolution	1440p30, 1080p60, 720p120, 480p240
Video Format	MP4 (H.264 Codec)
Lens Optics	82° HFOV (23mm) f/2.8 Aperture, -1% Extreme Low Distortion (Non-Fisheye) Glass Lens
Chipset	Novatek NTK96660
Capture Speed	RAW+JPG: 3 Seconds / Photo. JPG: 2 Seconds / Photo
Dimensions	59 x 41 x 30mm (Length x Height x Depth)
Memory Storage	Micro SD (Up To 128GB Card) (64GB Card ≈ 12,500 JPG, 1,750 RAW+JPG
Shutter Speed (s)	1/2000, 1/1000, 1/500*, 1/250, 1/125, 1/30, 2, 5, 10, 15, 20, 30, 60, Auto
Capture Mode	Single* / 3 Sequence / 10 Sequence

[9]

2.4 Field data

Field data consist of two part which is establishment of the ground control point (GCP) using GPS and collection of census data such as tree location, tree DBH and tree height.

2.5 Ground control point

Ground control point (GCP) is establish to rectify orthophoto image according to local coordinate system, Fig. 7 illustrates the establishment of the ground control point and coordinates point observation. GCP is essential to provide a correction on exterior orientation of the images. In this study, five (5) GCP's has been established along Sungai Papan using Rapid Static GPS observation as show in Fig. 8. The observation is conducted around 30 minutes for each GCP and the WGS84 coordinates that recorded is shown in Table 2.

Fig. 7 Observation of GPS on GCP

Fig. 8 Location of ground control point

Table 2 Coordinates of ground control point (WGS84)

No Stn.	Longitude	Latitude
1	101.401604	5.629822
2	101.400582	5.630151
3	101.400951	5.630100
4	101.400573	5.630874
5	101.400030	5.630734

2.6 Census data

The collection of census data is an essential especially tree DBH in order to estimate the aboveground biomass. The census data was collected on 3rd November 2015 and 350 sampling of tree DBH were measured within the 100m × 100 m experimental plot (Fig. 9). Tree DBH is recorded using diameter tape (Fig.10). For this study, the tree with DBH ≥ 10cm were measured and the aboveground biomass for each tree will be estimated by using allometric equation. Beside that, height of tree also recorded by using forester laser tree height as shown in Fig. 11 whereby to determine the differences between calculated and measured tree height. In addition, the name of the tree species has been recorded in this study during tree census.

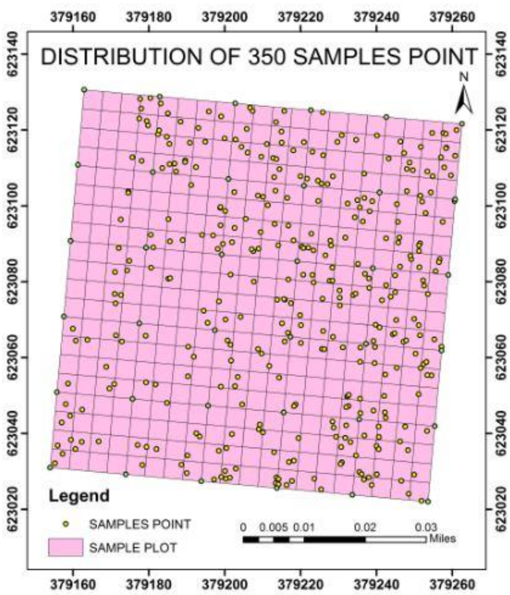


Fig. 9 Distribution of 350 samples point at 100 x 100m experimental plot

Fig. 10 Diameter tape

Fig. 11 Tree height laser instrument

2.7 Pre-processing

The primary data that needed in completion of this study is UAV multispectral images whreby be used to create an orthophoto mosaic. There are two type of orthophoto mosaics that created which are orthophoto of RGB and NIR. The images need to undergo geometric correction which is orthorectify. The images need to be orthorectified in order to overlay the grid of experimental plot and deployed a set of Ground Control Point (GCPs) as well as geometric model. Rational Polynomial Coefficient (RPC) model was the most popular method for geometric correction of a high- resolution image. Furthermore, it allows the corrected images using minimal GCPs [11]. Furthermore, UAV images will go through layer stacking process to create a vegetation indexes. The orthophoto for the RGB will be stacking into single layers which are red, blue, green and NIR, respectively. Layer stacking is essential because each vegetation indexes have different algorithm. Majorly, red and NIR layer were used to create vegetation indexes.

2.8 Processing

In this phase, the aboveground biomass and the tree biomass are calculated using established tropical allometric equations. Then is the extraction of value of eight vegetation indexes and sampling analysis that will be use in further process.

2.9 Tropical establish allometric equation

Hamdan et al. [12] stated that there are six biomass components within a tree which are foliage, stem, stump, branch, root and bark. Furthermore, the biomass proportion of this component varies according to tree species and the tree age itself. For example, the old tree has a high amount of biomass on the stem while the young tree has a high amount of biomass on the leaves and the roots. As Royal Belum Forest Reserve is classified in lowland tropical rainforest, thus tropical allometric equation will be used to calculate the aboveground biomass of the tree as shown in equation (1), (2) and (3). Meanwhile, the main parameter of this equation is DBH of the tree.

$$\frac{1}{\mathrm{H}} = \frac{1}{2\mathrm{D}} + \frac{1}{61} \tag{1}$$

Where H represent the total of tree height and D represent the tree DBH. From the values H and DBH after apply the algorithm then the dry mass of the stem ($\mathrm{M_S}$), branch ($\mathrm{M_b}$) and leaves ($\mathrm{M_l}$) of tree can be calculated.

$$M_S = 0.0313 \times (D^2\mathrm{H})^{0.9733} \tag{2}$$

$$M_b = 0.136 \times {M_S}^{1.070} \tag{3}$$

$$\frac{1}{\mathrm{M_l}} = \frac{1}{0.124\mathrm{M_s}^{0.794}} + \frac{1}{125} \tag{4}$$

Source: [13], [14]

Hence, the total aboveground biomass (TAGB) for a tree is summation of $(\mathrm{M_S}), (\mathrm{M_b})$ and $(\mathrm{M_l})$. The tree within the experimental plot will be calculated by using this equation.

2.10 Extraction of vegetation indexes

Estimation of aboveground biomass can be done by using remotely sensed data acquired from satellite, airborne or field sensors. Recently, satellite based vegetation indices (VI's) has become the common model for biomass estimation in many studies [15-17]. However, with the limitation of satellite based data, deployment of UAV in tropical rainforest is more practical. UAV provide real-time data and very high resolution images compare to certain satellite based data. Furthermore, deployment of UAV can overcome the cloud cover effect due to the low altitude during flight. Hence will increase the accuracy of the data and VI map that will be produced. In this study, eight vegetation indices are used in order to increase the accuracy of the biomass estimation. Table 3 shows the list of vegetation indexes and its formulas. Vegetation indexes are used in this study to interpret vegetation biomass and cover [18]. The eight vegetation indexes are used to determine the best correlation after regressed with aboveground biomass for next upscaling process.

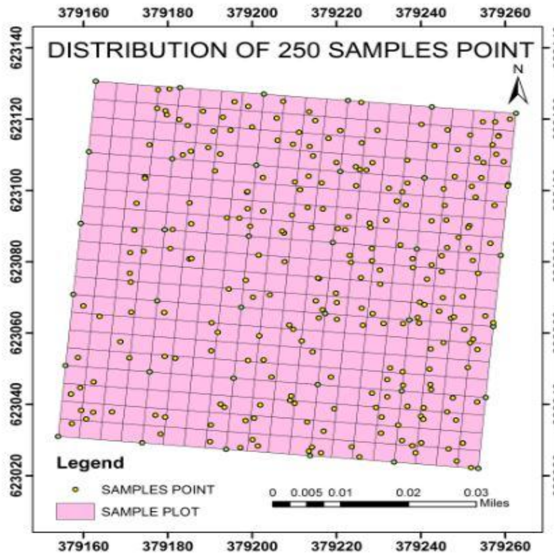
Table 3 The list of vegetation indices formula that used in this study

Vegetation Index	**Formula**	**Description**
Normalized Difference Vegetation Index (NDVI)	$\frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$	Use in order to measure the healthiness of the green vegetation
Optimized Soil Adjusted Vegetation Index (OSAVI)	$\frac{1.5 \times (\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red} + 0.16)}$	Used in areas with relatively sparse vegetation where soil is visible through the canopy
Difference Vegetation Index (DVI)	$\text{NIR} - \text{RED}$	To differentiate the difference between soil and vegetation.
Soil Adjusted Vegetation Index (SAVI)	$\frac{1.5 \times (\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red} + 0.5)}$	This index is similar to NDVI, but it suppresses the effects of soil pixels
Infrared Percentage Vegetation Index (IPVI)	$\frac{\text{NIR}}{\text{NIR} + \text{Red}}$	Functionally the same as NDVI, but it computationally faster
Modified Soil Adjusted Vegetation Index II (MSAVII)	$\frac{(2 \times \text{NIR} + 1\sqrt{(2 \times \text{NIR} + 1)^2 - 8 \times (\text{NIR} - \text{RED})}}{2}$	Calculate a soil brightness correction factor
Simple Ratio (SR)	$\frac{\text{NIR}}{\text{Red}}$	Ratio of the wavelength with highest reflectance for vegetation.
Green Ratio Vegetation Index (GRVI)	$\frac{\text{NIR}}{\text{Green}}$	This index is sensitive to photosynthetic rates in forest canopies

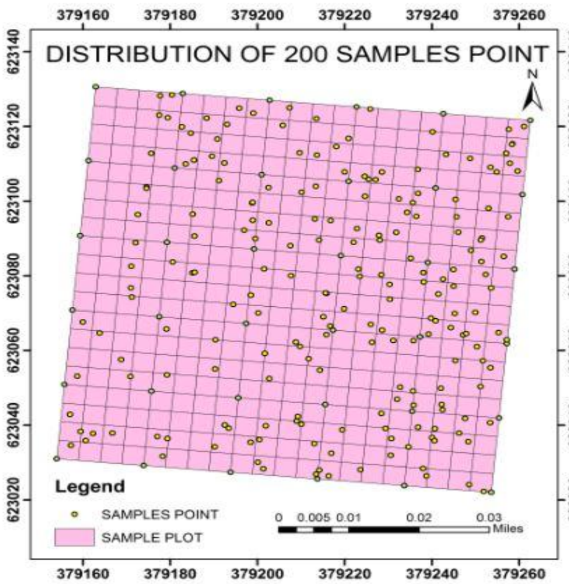
Source: [19-23]

2.11 Sampling analysis

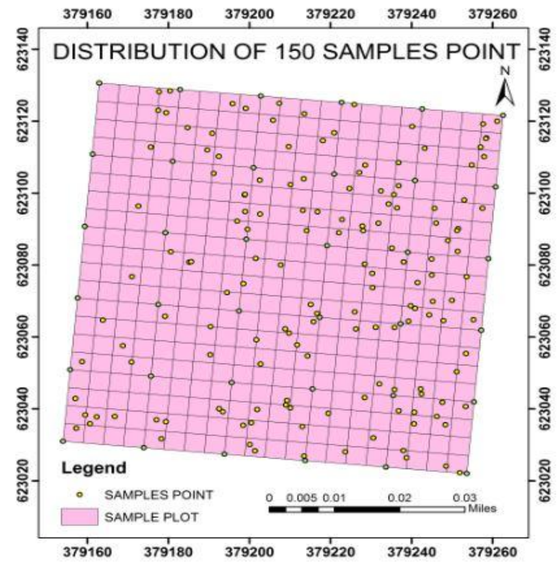
The sampling analysis process of 350 points is divided into two group of samples which are dependent samples whereby used 250 point samples and independent samples consist of 100 point samples. The selection of both samples is done by using random sampling based on the maximum and minimum measured DBH and well-distributed. Meanwhile, the correlation analysis is tested using 250, 200, 150 and 100 points, respectively for the dependent samples. The distribution of sample is illustrated in Fig. 12 (a), (b), (c), and (d). Subsequently the value of R^2 from each sample may differ but the sample that give the highest R^2 will give the best significant correlation.



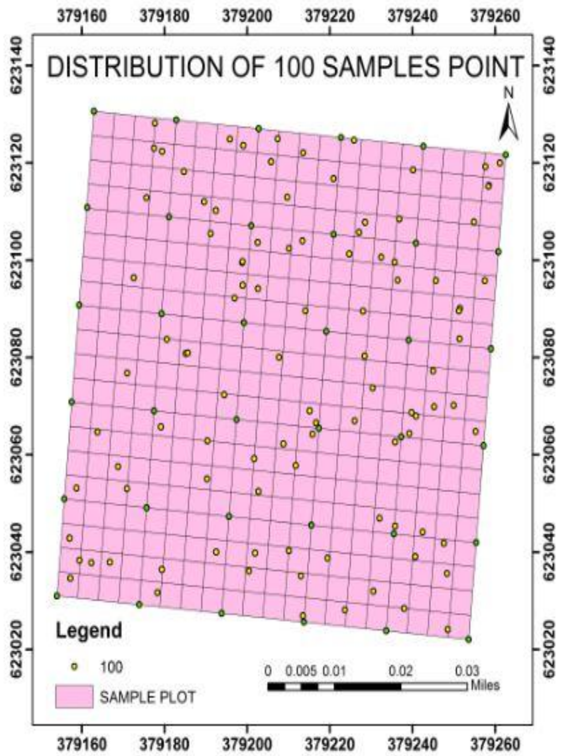
(a)



(b)



(c)



(d)

Fig. 12 Shows distribution of (a) 250; (b) 200; (c) 150; (d) 100; sample point in experimental plot With DBH range (a) 10<DBH<111; (b) 10<DBH<111; (c) 10<DBH<105; (d) 10<DBH<105

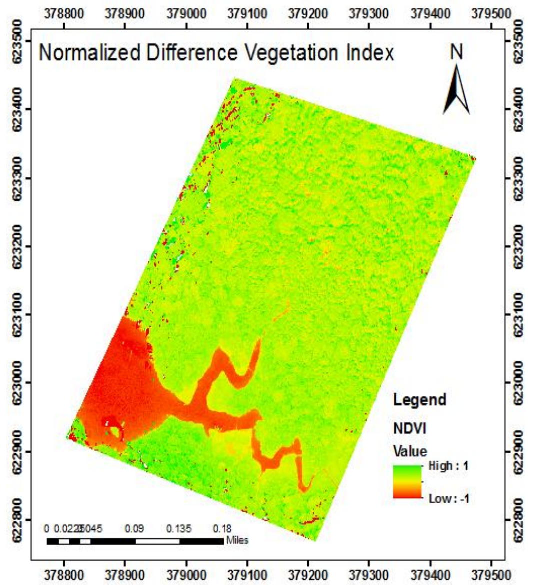
The correlation between the parameter is tested using linear and non-linear equation (linear, polynomial, logarithmic, power and exponential).

3. Results and Analysis

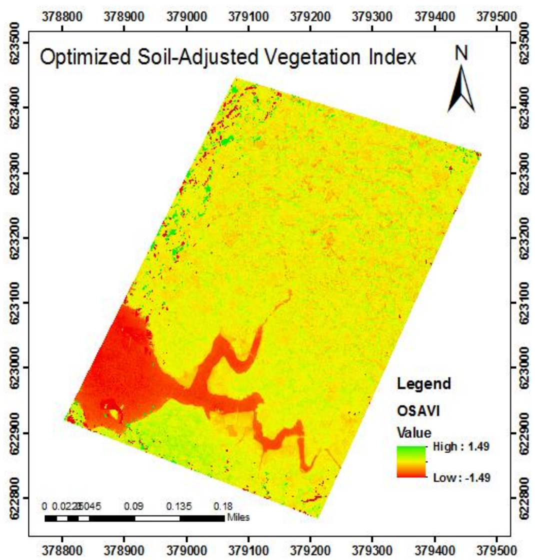
Final phase shows the eight maps of vegetation indexes that successfully produced using RGB and NIR images acquired from UAV platform. Each images been extracted based on VI formulas stated in Table 3. This final phase is also presents the highest correlation for each of sample test and the selected graph that shows the highest correlation between VI and TAGB. Furthermore, this phase also shows the result of RMSE and t-test analysis, respectively.

3.1 Vegetation indices

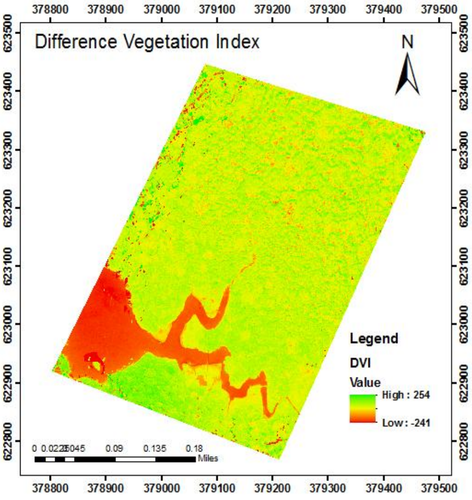
Each concentration of VI from UAV multispectral images shows in Fig.13. This study indicates that good resolution VI concentration map can be produced based on UAV multispectral images. The VI images are clearly shows their concentration whereby useful for further qualitative analysis as stated in description of Table 3.



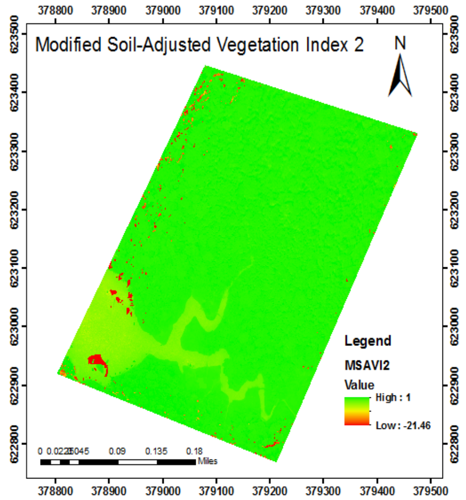
(a)



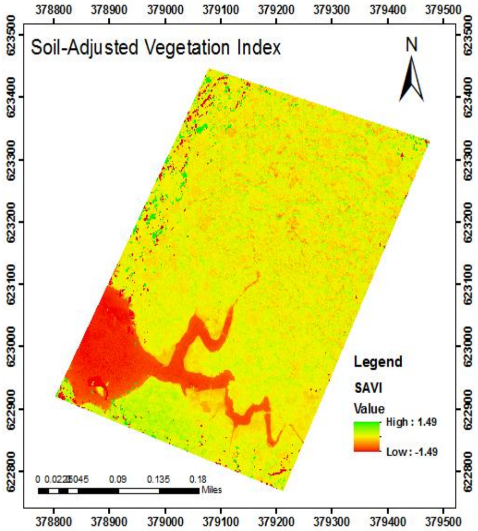
(b)



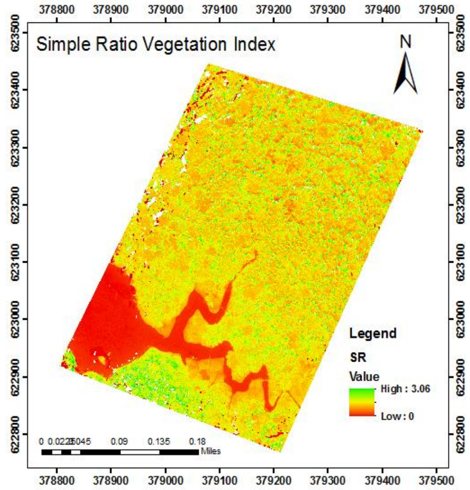
(c)



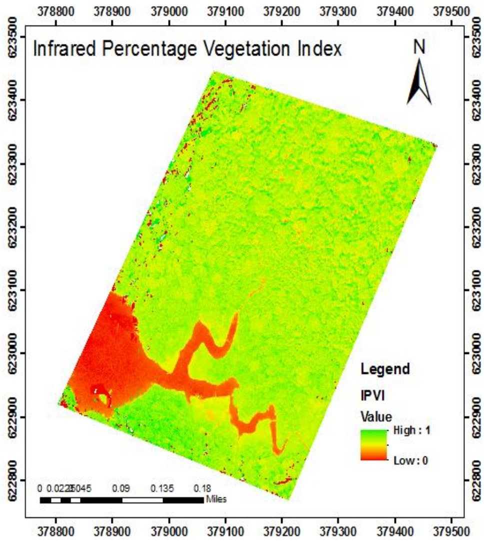
(f)



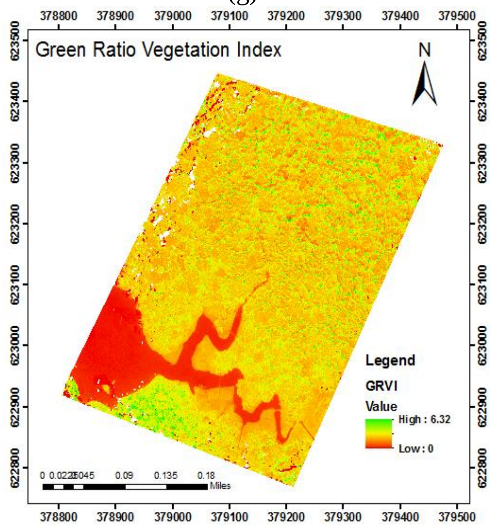
(d)



(g)



(e)



(h)

Fig. 13 Vegetation indices from UAV multispectral image (a) Normalized Difference Vegetation Index; (b) Optimized Soil Adjusted Vegetation Index; (c) Difference Vegetation Index; (d) Soil Adjusted Vegetation Index; (e) Infrared Percentage Vegetation Index; (f) Modified Soil Adjusted Vegetation Index 2; (g) Simple Ratio Vegetation Index; and (h) Green Ratio Vegetation Index.

3.2 Correlation analysis

Correlation analysis was carried out between total aboveground biomass and vegetation indexes to determine the best relationship between two components. Four groups of sample points have been tested in correlation analysis. The analysis indicates that correlation between TAGB and SR (NIR/Red) shows the highest significant correlation with R^2 = 0.7224 using random 100 independent sample points as shown in Table 4 .Fig. 14 shows the correlation graph between these two parameters.

Table 4 The highest significant correlation for 250, 200,150, and 100 sample with their R^2 and equation.

No. of sample	parameter	Correlation Equation	Type of Equation	R^2
250	TAGB VS MSAVI2	$y = 0.4002e^{-1.068x}$	Exponential	0.0173
200	TAGB VS SR	$y = 4.2295x^2 - 11.197x + 8.1896$	Polynomial	0.1383
150	TAGB VS NDVI	$y= 176.84x^2 - 33.863x + 1.9025$	Polynomial	0.5215
100	TAGB VS SR	$y= 39.467x^2 - 94.604x + 57.083$	Polynomial	0.7224

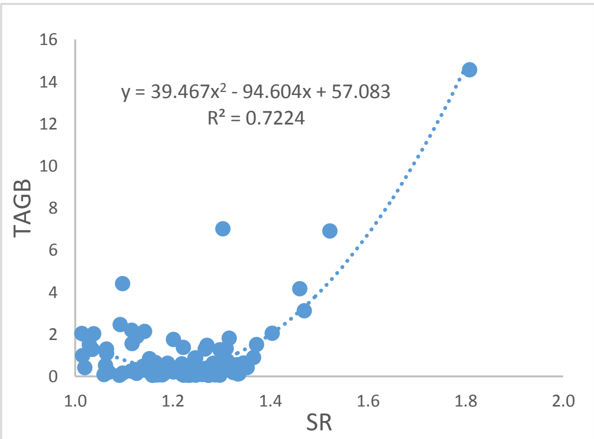


Fig. 14 Graph shows the trend sample for correlation between TAGB and SR at 100 random sample points

Based on the Table 4 and Fig. 14 as above best-fit line regression of SR using polynomial for 100 point samples is chosen to generate upscaling map for TAGB Sungai Papan, Royal Belum Forest Reserve. This VI is chosen because of successful gives the higher significant correlation compared to other VI.

3.3 Upscaling map

Based on the correlation between TAGB and VI, SR showed the highest significant correlation. Hence, SR correlation equation will be used to upscale TAGB from the experimental plot to the whole area of orthophoto image which is about 22 hectares. The upscaling map that produced shows the range of aboveground biomass for this area is from 0 and the maximum value is 138 tons for Sungai Papan, Royal Belum Forest Reserve**.** Fig. 15 illustrated the map of upscale TAGB.

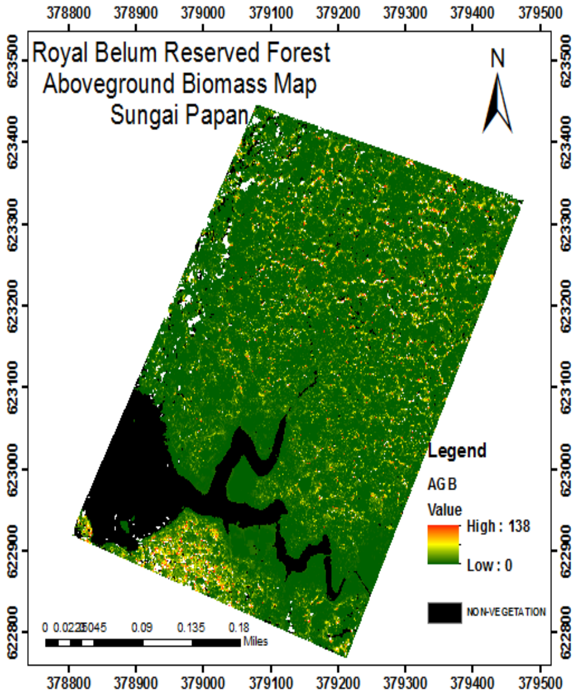


Fig. 15 Illustrated the concentration map of upscaling TAGB using correlation equation (TAGB and SR) at Sungai Papan (22 hectares), Royal Belum Forest Reserve, Perak

Based on Fig. 15, the distribution of TAGB is scattered around Sungai Papan but mainly concentrated at the southern part of Sungai Papan. The map shows that the most of the aboveground biomass of a tree is around 50 tons.

3.4 Analysis

The highest significant correlation equation is applied on 100 randomly chosen sample points. Root mean square error (RMSE) value is calculated based on the formula below to test the accuracy of the result:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(x_{1,t} - x_{2,t})^2}{n}} \quad (5)$$

By using equation (5), RMSE value that obtained is 1.170 and will be validate by using the statistical analysis t-test. The paired sample t-test is a statistical procedure that used to determine whether the mean difference between the selected two set of observation will be zero. The two sets data that used for this test is between the observed values of TAGB and the predicted value of TAGB.

Table 4: Pair sample correlation

TAGB observed &TAGB calculated	N	Correlation	Sig.
	100	.578	.000

Table 5: Pair sample test

TAGB observed - TAGB calculated	Mean	95% Confidence Interval of the Difference		t
		Lower	Upper	
	0.9872	0.8620	1.1124	15.647

Based on Table 4 and 5, the result shows that TAGB observed and TAGB calculated were positively correlated. On average, TAGB observed value were 0.9872 higher than TAGB calculated with 95% Confidence Interval [0.8620, 1.1124].

4. Summary

In conclusion, UAV platform has been widely used as a tool for forest monitoring and enforcement. Presently, there is no genuinely sources that similarly indicates that the use of UAV and compact sensor for biomass estimation at tropical rainforest. Thus, this study succesful to produce a suitable method for TAGB map for high density lowland tropical rainforest. Besides that, this study showed that the usage of upscaling method based on Unmanned Aerial Vehicle multispectral images had successfully estimate the total aboveground biomass (TAGB) for high density tropical rainforest. The statement mentioned as above is support by a strong correlation between the vegetation indexes and total aboveground biomass (TAGB). This study also shows that vegetation indices also can be derived from multispectral UAV data, thus introduced a new alternative method for assessing the total aboveground biomass (TAGB). Furthermore, multispectral UAV can be considered as a low-cost approach, hence minimize the resources which more economical.

Despite the limitation that caused by the characteristic of lowland tropical rainforest which is high density of tree and high dense cloud cover. Multispectral UAV and upscaling method successful to provide a rapid assessment for at Sungai Papan, Royal Belum Forest Reserve. The knowledge and information that obtained in this study can be used as a guideline for national level biomass assessment during the preliminary design phase.

Based on the upscaling map that produced, the concentration of biomass range for Sungai Papan is range from 0 to 138 ton. Furthermore, the TAGB is well distributed around Sungai Papan except at the southern part of Sungai Papan that shows the highest concentration of TAGB. The estimation of aboveground biomass in the forest is an essential to monitor the emission of carbon (C) stock. The changes of carbon (C) stock of the forest that greatly impact the climate changes and global warming which are the major issues for every nation, presently.

In so many ways, the advancement in remote sensing technology has truly benefited the forest community. The use of multispectral UAV data for forestry studies is suitable to improve in decision making process and ensure the sustainability of forest management practices. This study is also compliance with the statement that been released by UN-REDD [24] stated that every UN-REDD member countries are require to develop compatible methods, robust and cost effective for estimation of carbon stock in their own country.

Acknowledgement

The author would like to thank the State of Perak and Perak State Park Corporation who has been directly involved and gives cooperation to ensure this study successfully. Deepest gratitude to Ministry of Higher Education and University Teknologi Malaysia for providing research fund under FRGS-VOT 4F336, GUP Tier 1 VOT 14H44 and GUP Tier 1 VOT 20H01 that makes this research well executed with good financial support.

References

[1] Kelly, D., Gary O., Pat, S., and Chris, L. *Tropical Rainforest*, 3rd edition, (2000).

[2] Rhett, B. (2012). Types of forest (August 1, 2017), Retrieved from http://rainforests.mongabay.com/0103.htm.

[3] WWF-Malaysia., 2016. Lowland Forests (August 1, 2017). Retrieved fromhttp://www.wwf.org.my/about_wwf/what_we_do/forests_main/the_malaysian_rainforest/types_of_forests/lowland_forests/

[4] WWF-Malaysia., 2016. The Malaysian Rainforest (August 1, 2017). Retrieved fromhttp://www.wwf.org.my/about_wwf/what_we_do/forests_main/the_malaysian_rainforest/.

[5] Wangda, P. Upscaling the estimated forest carbon stock from VHR satellite image and airbone Lidar to rapid eye satellite image. (2012).

[6] UN-REDD, 2016, UN-REDD Programmed (August 1, 2017), Retrieved from http://www.un-redd.org/work-programme

[7] WWF-Malaysia., 2016. Royal Belum (August 1, 2017). Retrieved from http://www.wwf.org.my/about_wwf/what_we_do/forests_main/forest_protect/protect_projects/project_royal_belum/.

[8] Kurt, A.S., Richard, T.C., DeShazo, J.R., Matthew, D.P., Ashley, N.R. and Jeffrey, R.V. Creation of Malaysia's Royal Belum State Park: A Case Study of Conservation in a Developing Country. *Journal of Environment & Development*, 24(1), (2015), 54-81.

[9] Ponce-Hernandez, R., Koohafkan, P. and Antoine, J. Assessing carbon stocks and modelling win-win scenarios of carbon sequestration through land-use

changes. *Food and Agriculture Organization*, 1, (2004), p.1-156.

[10] MAPIR, 2018, Cameras (August 1, 2018), Retrieved from https://www.mapir.camera/pages/cameras

[11] Philip, C., Chuck, C. Pan-sharpening and Geometric Correction Worldview-2 satellite. (2010).

[12] Hamdan, O., Khali, A.H., Abd, R.K. Remotely Sensed l-band SAR data for tropical forest biomass estimation. *Journal of Tropical Forest Science*, 23(3), (2011), 318-327.

[13] Hoshozaki, K., Niiyama, K., Kimura, K., Yamashita, T., Bekku, Y., Okuda, T., Quah, E. S. and Supardi, N. Temporal and spatial variation of forest biomass in relation to stand dynamics in a mature, lowland tropical rainforest, Malaysia. (2004).

[14] Kato, R., Tadaki, Y. and Ogawa. Plant biomass and growth increment studies in Pasoh forest. *Malayan Nature Journal*, (1978), 30: 211-224.

[15] Foody, G.M., Boyd, D.S. and Cutler, M.E.J. Predictive relations of tropical forest biomass from Landsat TM data and their transferability between regions. *Remote Sensing of Environment*, 85(4), (2003), 463-474.

[16] Zheng, D., Rademacher, J., Chen, J., Crow, T., Bresee, M., LeMoine, J., and Ryu, S. Estimating aboveground biomass using Landsat 7 ETM+ data across a managed landscape in northern Wisconsin, USA. *Remote Sensing of Environment*, 93(3), (2004), 402-411.

[17] Schlerf, M., Alzberger, C. and Hill, J. Remote sensing of forest biophysical variables using HyMap imaging spectrometer data. *Remote Sensing of Environment*, 95, (2005), 177-194.

[18] Patel, N.K., Saxena, R.K., and Shiwalkar, A. Study of fractional vegetation cover using high spectral resolution data. *Journal of the Indian Society of Remote Sensing*, 35, (2007), 73-79.

[19] Rondeaux, G., Steven, M. and Baret, F. Optimization of Soil-Adjusted Vegetation Indices. *Remote Sensing of Environment*, 55, (1996), 95-107.

[20] Tucker, C. Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. *Remote Sensing of Environment*, 8, (1979), 127–150.

[21] Huete, A. A Soil-Adjusted Vegetation Index (SAVI). *Remote Sensing of Environment*, 25, (1988), 295-309.

[22] Crippen, R. Calculating the Vegetation Index Faster. *Remote Sensing of Environment*, 34, (1990), 71-73.

[23] Sripada, R., et al. Aerial Colour Infrared Photography for Determining Early In-season Nitrogen Requirements in Corn. *Agronomy Journal*, 98, (2006), 968-977.