Estimating above Ground Biomass of *Fraxinus griffithii* C. B. Clarke using Remotely Sensed Data in Royal Project Area, Chiang Mai, Thailand

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Abstract
This research aims to estimate above ground biomass (AGB) of Fraxinus griffithii C. B. Clarke from remotely sensed data. The methodology includes analyzing 13 vegetation indices from LANDSAT 8 OLI satellite image which was captured on 7 March 2015. The AGB from previous researchers were calculated using by allometric equation. The allometric equation could be done by collecting diameter at breast height and height of F. griffithii in 26 sample plots of 7 royal project stations in Chiang Mai province including Mok Jam station, Kae Noi station, Nong Kiew station, Huy Luk station, Nong Hoy station, AngKhang station and Pang Da station. There was also an analysis of vegetation indices which influences to AGB. This analysis was carried out by correlation and stepwise regression. The study found that Brightness, Greenness and Wetness related with AGB. Moreover, Brightness, Ratio and Greenness influences the calculation of AGB. Model validation could predict estimation of AGB with 63.19 percent Accuracy.

1. Introduction

Recently, high altitude regions in the Chiang Mai, Thailand have confronted with severe concerns of declining forest area. Furthermore, the number of people residing in high elevation areas has been growing rapidly. This has also increased the demand of wood in these areas (Jindawong, 2010). Planting is one method for recovering the destroyed areas. Nowadays, several projects which are from public and private sector try to support plantation (Watcharinrat et al., 2003). The Royal Project Foundation is one of the supporters who suggests the planting of exotic tree species to agriculturists. Perennial plants and bamboos from Taiwan were used for the trial planting. For example, *Acacia confusa*, *Cinnamomum camphora*, *Liquidambar formosana*, *Paulownia taiwaniana*, and *Fraxinus griffithii* C. B. Clarke (Thaiutsa, 2012)

The study found that *F. griffithii* is suitable for furniture making (Jindawong et al., 2002). As it is durable with the polish. Apart from this, agriculturists in high elevation areas would also like to plant this species (Jindawong, 2010). Therefore, the measurement of growth and products from *F. griffithii* can support plantation. Primary measurement is normally done by biomass measurement pattern. The measurement consists of biomass in each section including trunk, limb, leaf, and root. Generally, only the above ground biomass (AGB) is applied (Domrongsutsiri, 2001)

An estimation of AGB needs to be executed on site by cutting wood and bringing every part for drying. This process uses high expenditure and time, yet it has high accuracy. Nevertheless, there is the problem of planting *F. griffithii* nowadays. A few numbers of agriculturists plant this species and rarely plant in some places of Royal Project stations. Thus, this study has chosen allometric method from previous scholars for the calculation of AGB. This method can save expenditure and time. Hence, this research used satellite images for estimating AGB with vegetation indices. Vegetation in the record of wavelength from Landsat 8 OLI (Operational Land Imager) is applied. Although, it has low resolution (30 meters in band 1 – 7, 9), it is suitable for large areas. Visible bands, near infrared band, and shortwave infrared band were chosen for the calculation with mathematic equation. The outcome can provide quick and accurate estimate AGB especially in large remote areas. It also provides benefits to the sustainable management of forest and land resources. This study can encourage agriculturists to plant trees for reducing reforestation. The study was carried out to estimate AGB of *F. griffithii* by using remotely sensed data in Royal Project Area, Chiang Mai province.

2. Study Site

Study sites are 7 areas from 28 Royal Project stations in Chiang Mai province, Thailand. The purposive sampling is chosen. The study sites are located at latitude 18° 51′ 18″ N - 20° 4′ 33″ N and longitude 98° 45′ 46″ E - 99° 28′ 22″ E. It can be seen in Figure 1. The study areas which are located at a height of 1,000 meters above sea level includes the AngKhang Station, Nong Hoy station and Kae Noi station. The rest are located at a height below 1,000 meters. Average temperature in study areas is below 20 celsius. Average rainfall is 1,507 millimeters per year. People who live in upper area are hilltribes while people who live in flat area are the combination between hilltribes and Thais.

3. Materials and Methods

The image from LANDSAT 8 OLI satellite image which captured on 7 March 2015. It was modified by geometric correction and atmospheric correction (DN to reflectance) (Kiyoshi, 2005) after that vegetation indices were applied from the following.

3.1 Geometric Correction

This study applied image to map correction (Jensen, 1996) by used topographic map L7018 for the reference. Geometric equation is used with second order polynomial. Error was less than 1 pixel. Resampling was nearest neighbour interpolation. Mosaic of 2 scenes of satellite images were selected for the analysis.

3.2 Atmospheric Correction

Calculating reflectance value from satellite data from the following equation:

$$P\lambda' = M_p Q_{cal} + A_p$$

Equation 1

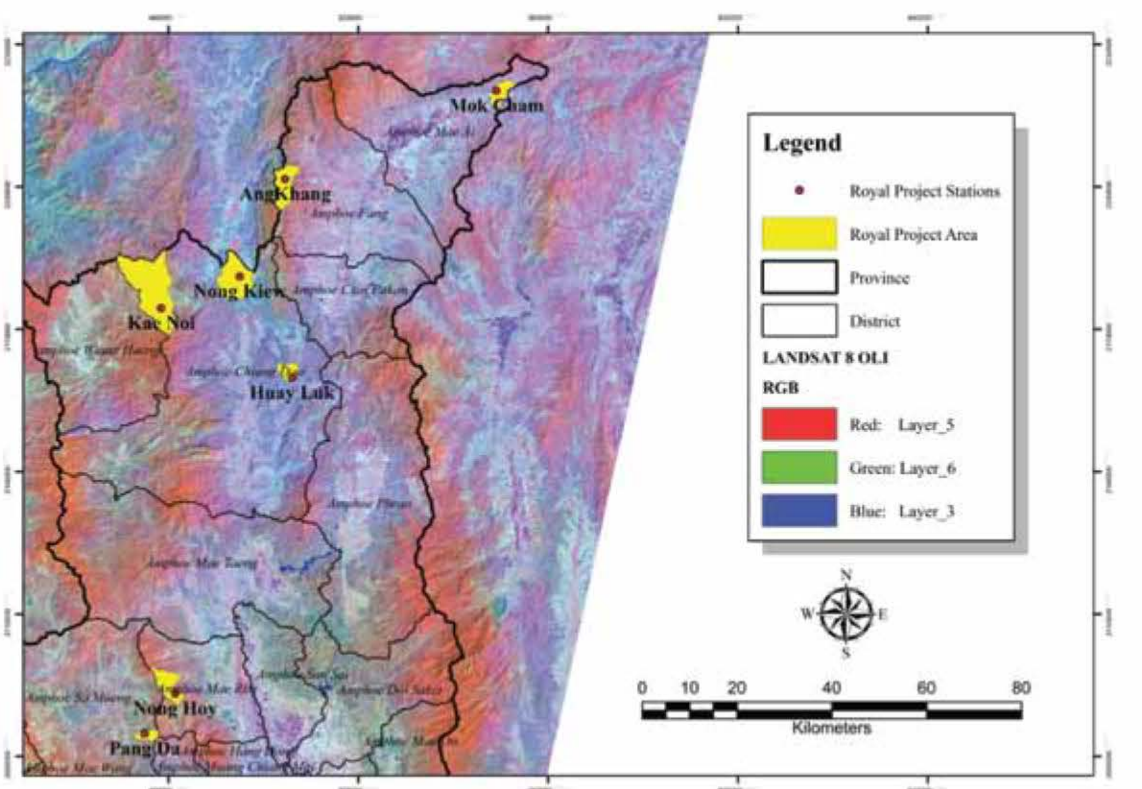

Figure 1: False colour composite of LANDSAT 8 OLI (R:G:B, 5:6:3) consisting of study area

Which:

Where, $P\lambda'$ = TOA (Top of atmosphere) planetary reflectance, without correction for solar angle.
M p = Band - specific multiplicative rescaling factor from the metadata.
A p = Band - specific additive rescaling factor from the metadata.
Q cal = Quantized and calibrated standard product pixel value (DN).

Then, correcting the reflectance value with sun angle following equation:

$$P\lambda = \frac{P\lambda'}{\cos\theta SZ}$$

$$P\lambda = \frac{P\lambda'}{\sin\theta SE}$$

Equation 2

Which:

$P\lambda$ = TOA (Top of atmosphere) planetary reflectance
$P\lambda'$ = TOA (Top of atmosphere) planetary reflectance without correction for solar angle.
θSZ = Local solar zenith angle; $\theta SZ = 90° - \theta SE$
θSE = Local sun elevation angle.
(U.S. Geological Survey, 2016)

3.3 The Analysis of Vegetation Indices

In forest field works, the reflectance and absorption energy of leaves are utilized to develop vegetation indices which refers to the abundance and biomass of forest. Vegetation indices are the simple technique which is used to extract information for a quantitative amount of vegetation, or greenness in each pixel of the image data. Vegetation indices involve two or more wavelengths for computation. This study has used vegetation indices in various forms which are involved in forest types such as Teak and Eucalyptus. Several vegetation indices are numerated as shown in Table 1.

Table 1: Vegetation indices

Vegetation Indices	Explanation of Symbols	Author
$RATIO = \frac{NIR}{R}$	SWIR = Shortwave infrared	Birth and McVey (1968) cited in Silleos et al., (2006)
$DVI = NIR - R$	NIR = near infrared R = red	Tucker (1980) cited in Barzegar et al., (2015)
$NDVI = \frac{NIR-R}{NIR+R}$	G = green B = blue	Rouse et al., (1974) cited in Silleos et al., (2006)
$SAVI = \frac{NIR-R}{NIR+R}(1+L)$	L = soil	Huete (1988) cited in Silleos et al., (2006)
$TVI = \sqrt{\frac{NIR-R}{NIR+R}+0.5}$	Adjustment factor C1 and C2 are constants.	Deering et al. (1975) cited in Silleos et al., (2006)
$Square\ root = \sqrt{\frac{NIR}{R}}$	G is a gain factor a = intercept of soil line b = slope of soil line	Tucker (1977) cited in Henrich and Bruser (2017)
$NDWI = \frac{NIR-SWIR}{NIR+SWIR}$		Gao (1996) cited in Barzegar et al., (2015)
Brightness = (0.3029)*B + (0.2786)*G + (0.4733)*R + (0.5599)*NIR + (0.508) * SWIR1 + (0.1872)*SWIR2		Baig et al., (2014)
Greenness = (-0.2941)*B + (-0.243)*G + (-0.5424)*R + (0.7276)* NIR + (0.0713)*SWIR1 + (-0.1608) * SWIR2		Baig et al., (2014)
Wetness = (0.1511)*B + (0.1973)*G + (0.3283)* R + (0.3407) NIR + (-0.7117)*SWIR1 + (-0.4559)*SWIR2		Baig et al., (2014)
$PVI = \frac{(NIR-a) \times (R+b)}{\sqrt{1+a^2}}$		Bannari et al., (1996) cited in Silleos et al., (2006)
$WDVI = NIR - b * R$		Richardson and Wiegand (1977) cited in Silleos et al. (2006)
$EVI = G * \frac{NIR-R}{NIR+C1R-C2B+L}(1+L)$		Huete et al. (1999) cited in Silleos et al. (2006)

Source: Jensen, 1996, Gao, 2009 and Silleos et al., 2006 and http://grindgis.com

3.4 The Analysis Process of the Above Ground Biomass

Plantation areas of *F. griffithii* were discovered from village woodlot project officers of Royal Project stations. Global Positioning System (GPS) data has been used to identify the plantation areas. The size of 10x10 meters of sample tree plots were set in 26 plots of 7 Royal Project stations. Then, there were the measurement of Diameter at breast height (D) and height (H) of every tree in sample tree plots. The allometric equation from previous study was used in the following:

Biomass of stem	$W_s = 0.0767\ (D^2H)^{0.8534}$
Biomass of branch	$W_b = 0.0025\ (D^2H)^{1.1009}$
Biomass of leaf	$W_l = 0.0012\ (D^2H)^{0.478}$
Above ground biomass	$\mathbf{W_t = W_s + W_b + W_l}$

(Pakoktom, 2013)

4. Results

Results by analysing AGB from the LANDSAT8 OLI satellite image are explained as below:

- The above ground biomass from allometric equation, and the analysis of vegetation indices from LANDSAT 8 OLI are shown in Table 2.

  The correlation between above ground biomass and vegetation indices by using Pearson Product Moment Correlation Coefficient are in the following:

1) AGB related with Brightness with correlation coefficient -0.595 ($p \le .01$)
2) AGB related with Greenness with correlation coefficient 0.431 ($p \le .05$)
3) AGB related with Wetness with correlation coefficient 0.442 ($p \le .05$)

Table 2: Calculation of above ground biomass and analysis of vegetation indices from Landsat 8 OLI

Area	AGB	Ratio	DVI	NDVI	SAVI	Sqrt	TVI	NDWI	PVI	WDVI	Brightness	Greenness	Wetness	EVI
1. Nong Hoy	109.15	0.27	3.90	0.59	0.42	1.97	1.03	-0.70	0.12	0.10	2.62	-0.86	-2.28	-0.05
2. Angkhang	66.96	0.24	5.16	0.67	0.42	2.27	1.08	-0.72	0.17	0.17	2.02	-0.52	-1.08	-0.06
3. Angkhang	232.11	0.27	5.36	0.69	0.45	2.31	1.09	-0.70	0.19	0.19	2.09	-0.50	-1.14	-0.07
4. Angkhang	477.58	0.14	3.36	0.54	0.28	1.83	1.02	-0.76	0.10	0.10	1.74	-0.56	-0.89	-0.04
5. Angkhang	262.58	0.21	5.01	0.67	0.39	2.24	1.08	-0.67	0.15	0.15	1.70	-0.50	-0.70	-0.06
6. Nong Khew	43.35	0.21	3.48	0.55	0.36	1.87	1.02	-0.79	0.15	0.15	2.87	-0.83	-1.77	-0.04
7. Pang Da	243.81	0.18	2.68	0.46	0.39	1.64	1.06	-0.75	0.13	0.12	2.86	-0.92	-2.45	-0.06
8. Pang Da	200.40	0.19	3.57	0.56	0.43	1.89	1.05	-0.76	0.14	0.13	2.93	-0.95	-2.47	-0.05
9. Mok Cham	36.84	0.26	4.63	0.64	0.44	2.15	1.06	-0.73	0.19	0.19	2.67	-0.82	-1.23	-0.05
10. Mok Cham	96.15	0.30	5.07	0.43	0.48	2.25	1.08	-0.82	0.10	0.10	2.86	-0.98	-1.64	-0.05
11. Mok Cham	1.84	0.21	3.07	0.50	0.34	1.75	1.00	-0.82	0.15	0.15	3.36	-0.94	-2.34	-0.04
12. Huay Luk	70.77	0.19	2.98	0.50	0.33	1.73	1.00	-0.83	0.14	0.14	3.37	-1.05	-2.15	-0.03
13. Huay Luk	50.85	0.15	2.37	0.40	0.26	1.54	0.95	-0.85	0.11	0.11	3.55	-1.12	-2.47	-0.02
14. Kae Noi	120.64	0.21	3.65	0.56	0.36	1.91	1.03	-0.77	0.15	0.16	2.38	-0.64	-1.53	-0.05
15. Kae Noi	110.29	0.23	4.05	0.60	0.39	2.01	1.05	-0.78	0.16	0.15	2.47	-0.60	-1.70	-0.06
16. Kae Noi	21.87	0.17	2.75	0.47	0.29	1.94	1.04	-0.81	0.12	0.12	2.83	-0.57	-2.26	-0.04
17. Angkhang	180.48	0.17	4.08	0.60	0.33	2.02	1.05	-0.74	0.12	0.12	1.82	-0.57	-0.89	-0.05
18. Angkhang	320.29	0.18	4.21	0.62	0.34	2.05	1.06	-0.74	0.12	0.12	1.81	-0.56	-0.88	-0.05
19. Angkhang	142.03	0.24	5.48	0.69	0.42	2.34	1.09	-0.68	0.16	0.17	1.85	-0.50	-0.86	-0.07
20. Angkhang	113.43	0.20	6.49	0.65	0.37	2.16	1.07	-0.70	0.14	0.14	1.73	-0.51	-0.76	-0.06
21. Angkhang	78.41	0.22	4.35	0.63	0.38	2.08	1.06	-0.74	0.15	0.15	2.14	-0.59	-1.19	-0.05
22. Angkhang	51.22	0.30	6.35	0.72	0.49	2.22	1.07	-0.65	0.18	0.18	2.09	-0.55	-1.06	-0.07
23. Angkhang	349.73	0.21	4.95	0.66	0.38	2.23	1.08	-0.71	0.15	0.15	1.78	-0.49	-0.88	-0.06
24.Nong Khew	91.23	0.18	2.89	0.48	0.32	1.70	0.99	-0.82	0.13	0.13	3.14	-0.92	-0.88	-0.04
25.Nong Khew	41.19	0.11	1.83	0.29	0.19	1.35	0.89	-0.87	0.07	0.08	3.72	-1.13	-2.23	-0.02
26.Nong Khew	42.09	0.15	2.72	0.46	0.28	1.65	0.98	-0.82	0.10	0.11	2.78	-0.88	-3.03	-0.03

Table 3: The result of correlation analysis among AGB with vegetation indices

	AGB	Ratio	DVI	NDVI	SAVI	Sqrt	TVI	NDWI	PVI	WDVI	Brightness	Greenness	Wetness	EVI
AGB	1	.160	-.138	.248	.035	.219	.348	.380	-.083	.380	-.595**	.431*	.442*	-.313
Ratio		1	.191	.838**	.756**	.913**	.805**	.821**	.614**	.609**	-.745**	.692**	.699**	-.828**
DVI			1	.083	-.227	.181	-.041	-.126	.119	.282	-.180	.303	.442*	.081
NDVI				1	.679**	.854**	.812**	.909**	.788**	.756**	-.819**	.813**	.685**	-.834**
SAVI					1	.782**	.820**	.677**	.698**	.613**	-.400*	.344	.324	-.812**
Sqrt						1	.911**	.790**	.645**	.631**	-.767**	.760	.682**	-.839**
TVI							1	.790**	.639**	.582**	-.824**	.725**	.567**	-.900**
NDWI								1	.620	.571**	-.824**	.758**	.629**	-.871**
PVI									1	.974**	-.369	.484*	.404*	-.693**
WDVI										1	-.374	.502**	.442**	-.642**
Brightness											1	-.926**	-.777**	.732**
Greenness												1	.732**	-.734**
Wetness													1	-.584**
EVI														1

Tables 4: The analysis of vegetation indices which influences to above ground biomass

	Unstandardized Coefficients		**Standardized Coefficients**		
Model	**B**	Std.Error	Beta	**t**	**Sig.**
Constant	914.621	155.685		5.875	.000
Brightness Ratio	-342.739	69.334	-1.834	-4.943	.000
Greenness	-60.423	18.510	-.633	-3.264	.004
	-442.025	182.682	-.829	-2.420	.024

- Analysis of correlation between AGB and vegetation indices.

There was no relation among AGB and others vegetation indices. It was shown in Table 3

- The estimation of AGB from the remote sensed data.

The results from the estimation of AGB were found by defining dependent variable which is above ground biomass. Independent variables are 13 vegetation indices including Ratio, DVI, NDVI, SAVI, Sqrt, TVI, NDWI, Brightness, Greenness, Wetness, PVI, WDVI and EVI. The analysis of vegetation indices which influences to above ground biomass with stepwise regression was shown in Table 4. Table 4 can create an equation to evaluate aboveground biomass is following:

$$AGB = 941.621 - 342.739 * (Brightness) - 60.423*(Ratio) - 442.025*(Greenness) \quad (R^2 = 0.632)$$

Equation 3

F. griffithii is exotic tree species which has small trunk, branch, and leaves. The light can pass through the ground easily. Hence, ABG of this species is less than other exotic tree species. This is due to small leaves of *F. griffithii,* that is the reason for Ratio to influence AGB. Ratio can be calculated between ratio of red band and infrared band. There is less reflection of infrared. Moreover, Brightness relates with a reflection from soil. It was shown that space between planting of *F. griffithii* influences to soil value. Moreover, Greenness completely relates with forest, so plots of the ***Fraxinus griffithii*** C.B.Clarke. Contain lot of trees which influence to Greenness.

The result of the estimation of AGB from remotely sensed data with stepwise regression can be seen in table 5. The analysis found that the total AGB of *F. griffithii* across the Royal Project stations is 4,257.36 ton/hectare.

- Model Validation: The validity of models for estimating AGB from the multiple regression can be checked by comparing between the above ground biomass from stepwise regression equation (estimated value) with the above ground biomass from allometric equation (observed value). Linear regression analysis is used for predicting the relationship. The equation is y = 1x – 27.002. The estimated value can predict the observed value with 63.19 percent ($R^2 = 0.6319$). It can be seen in Figure 2.

5 .Conclusion and Future Research

This research aims to estimate aboveground biomass (AGB) of *F. griffithii* from remotely sensed data in The Royal Project areas, Chiang Mai province. The methodology was done by analyzing 13 vegetation indices from LANDSAT 8 OLI satellite image which was capture on 7 March 2015. The analysis of above ground biomass from previous scholars were calculated from allometric equation. The equation was formed by collecting diameter at breast height and the height of *F. griffithii* in 26 sample plots of 7 royal project stations in Chiang Mai province including Mok Jam station, Kae Noi station, Nong Kiew station, Huy Luk station, Nong Hoy station, AngKhang station and Pang Da station.

Table 5: The estimate of AGB from remotely sensed data with stepwise regression (unit: ton/hectare)

Station	Estimate ABG	Station	Estimate ABG
1. Nong Hoy	188.16	14. Kae Noi	188.27
2. Angkhang	167.38	15. Kae Noi	115.58
3. Angkhang	122.468	16. Kae Noi	57.48
4. Angkhang	389.79	17. Angkhang	323.28
5. Angkhang	277.28	18. Angkhang	314.44
6. Nong Khew	114.59	19. Angkhang	197.47
7. Pang Da	206.17	20. Angkhang	181.99
8. Mok Cham	141.63	21. Angkhang	206.13
9. Mok Cham	109.23	22. Angkhang	84.74
10. Mok Cham	88.28	23. Angkhang	249.06
11. Huay Luk	20.048	24.Nong Khew	97.48
12. Huay Luk	70.68	25.Nong Khew	55.57
13. Pang Da	76.78	26.Nong Khew	213.46

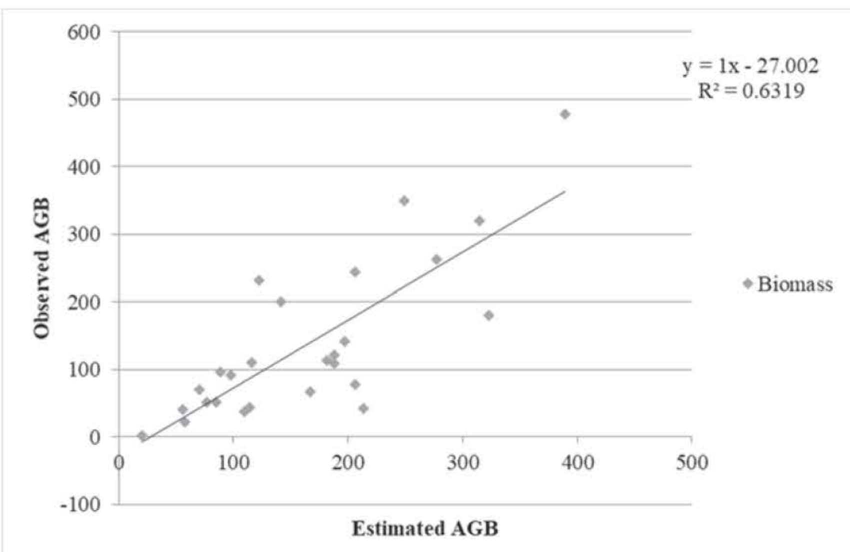

Figure 2: The relation between observed data and estimated data

The study with Pearson Product Moment Correlation Coefficient found that AGB related with Brightness (r = -0.595, p <= .01), Greenness (r = 0.431, p <= .05) and Wetness (r = 0.442, p <= .05). Stepwise regression is used for estimating AGB with the 13 vegetation indices. The results showed that the Brightness, Ratio and Greenness were variables which influenced the estimation of aboveground biomass. The equation used for computation was AGB = 941.621 – 342.739 * (Brightness) - 60.423*(Ratio) – 442.025*(Greenness) ($R^2 = 0.632$). Total AGB is 4,257.36 ton/hectare. This study has agreed with the study by Chailangka (2010) which studied about an estimation of above ground biomass from Eucalyptus plantation by using remotely sensed data: case study of Nakhonratchasima province. Greenness and NDWI are vegetation indices which can be estimated by the above ground biomass. This study has also agreed with Srisuwan et al., (2009) who studied the biomass estimation of Teak plantation from Landsat TM data.

The study found that biomass of Teak mostly related with greenness. On the other hand, the result was different from Zheng et al., (2004) who studied the combination of remote sensing imagery and forest age inventory for biomass mapping. Landsat 7 ETM+ was used for calculating 5 vegetation indices. The study found that an estimation of AGB for hardwood forest strongly related to stand age and near infrared reflectance. Whereas, AGB estimation for pine forest strongly related to correct normalized difference vegetation index. Model validation has moderate reliability. Simple linear regression was applied. It was found that estimated value of AGB can predict observed value of AGB with 63.19 percent. This model has limitation in a few tree plots. This is because agriculturists did not pay much attention for the plantation of *F. griffithii* in each royal project station. The further research should match with the satellite image data and field work. Sampling should be done based on the age. There should be more sample sites and tree plots. Last but not least, future research should use other satellite images and comparison among other exotic tree species.

Acknowledgement

This research was supported by a grant from Sustainable Land Use and Natural Resource Management, Graduate school, Kasetsart University.

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