การเปรียบเทียบความแตกต่างของสมการมวลชีวภาพของไม้ยืนต้น 4 ชนิดพันธุ์ บริเวณป่าผสมผลัดใบที่เคยถูกทำลาย อำเภอไทรโยค จังหวัดกาญจนบุรี

Comparing Difference of Biomass Equations in Four Dominant Tree Species in Degrade Mixed Deciduous Forest, Sai Yok, Kanchanaburi

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บทคัดย่อ

สมการมวลชีวภาพถูกพัฒนาขึ้นเพื่อติดตามการเปลี่ยนแปลงของปริมาณคาร์บอนที่สะสมในเนื้อไม้ ความสัมพันธ์ดังกล่าวอยู่ในรูปสมการเชิงเส้นระหว่างน้ำหนักแห้งของต้นไม้ (*B*) เส้นผ่านศูนย์กลางที่ความสูงเพียงอก (*D*) ความสูง (*H*) ความหนาแน่นของเนื้อไม้ (ρ) จากการเปรียบความสัมพันธ์ของตัวแปรในรูปสมการเชิงเส้นของไม้ยืนต้น 4 ชนิดพันธุ์ ได้แก่ *Sterculia pexa*, *Millettia brandisiana*, *Grewia eriocarpa* และ *Bridelia ovata* โดย *B* เป็นตัวแปรตาม และตัวแปรต้นคือ D^2H และ ρD^2H ผลลัพธ์จากการเปรียบเทียบสมการเชิงเส้นในรูป $\ln(B) = c + \beta \ln(D^2H)$ พบว่ามีความแตกต่างของสมการมวลชีวภาพระหว่าง *Sterculia pexa* และ *Millettia brandisiana*, *Millettia brandisiana* และ *Grewia eriocarpa*, *Millettia brandisiana* และ *Bridelia ovata* ส่วนสมการมวลชีวภาพระหว่าง *Sterculia pexa* และ *Grewia eriocarpa*, *Sterculia pexa* และ *Bridelia ovata*, *Grewia eriocarpa* และ *Bridelia ovata* พบว่าไม่มีความแตกต่างกัน เมื่อเปรียบเทียบสมการในรูป $\ln(B) = c + \alpha \ln(\rho D^2H)$ พบว่ามีความแตกต่างของสมการมวลชีวภาพระหว่าง *Sterculia pexa* และ *Millettia brandisiana*, *Sterculia pexa* และ *Bridelia ovata*, *Millettia brandisiana* และ *Grewia eriocarpa* ส่วนสมการมวลชีวภาพระหว่าง *Sterculia pexa* และ *Grewia eriocarpa*, *Millettia brandisiana* และ *Bridelia ovata*, *Grewia eriocarpa* และ *Bridelia ovata* พบว่าไม่มีความแตกต่างกัน จากสมการชี้ให้เห็นว่าความหนาแน่นของเนื้อไม้ (ρ) เป็นตัวแปรที่สำคัญต่อความแตกต่างของสมการ

คำสำคัญ : ป่าไม้ มวลชีวภาพ สมการแอลโลเมตริก

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ABSTRACT

Allometric regression model is the important application to track biomass and carbon in tree of forest. It is a relationship among dry weigh of biomass (*B*), diameter at breast height (*D*), height (*H*) and wood specific gravity (ρ). Comparing the allometric regression, *B* is a dependent variable and D^2H and ρD^2H is an independent variable among four tree species in mixed deciduous forest. Example for *Sterculia pexa*, *Millettia brandisiana*, *Grewia eriocarpa* and *Bridelia ovata*, the result of compared allometric regression in form $\ln(B) = c + \beta \ln(D^2H)$ reveals that there are significant differences between *Sterculia pexa* and *Millettia brandisiana, Millettia brandisiana* and *Grewia eriocarpa*. However, there is no significant difference between *Sterculia pexa* and *Grewia eriocarpa*, *Sterculia pexa* and *Bridelia ovata, Millettia brandisiana* and *Bridelia ovata, Grewia eriocarpa* and *Bridelia ovata*. Revaluate of testing for difference of slopes among four linear regressions in form $\ln(B) = c + \alpha \ln(\rho D^2H)$. There are significant difference between *Sterculia pexa* and *Millettia brandisiana, Sterculia pexa* and *Bridelia ovata, Millettia brandisiana* and *Grewia eriocarpa*. On the other hand, there is no significant difference between*, Sterculia pexa* and *Grewia eriocarpa*, *Millettia brandisiana* and *Bridelia ovata, Grewia eriocarpa* and *Bridelia ovata*. Regression form indicates that the most essential variable for improving species-specific regression is wood specific gravity.

Keywords : Forest, Biomass, Allometric regression model

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INTRODUCTION

One of the large sources of uncertainty in all estimate of biomass and carbon estimation in tropical forest is the lack of standard models for converting tree measurements to aboveground biomass estimates (1). Progress of biomass and carbon estimation has been less in Thailand tropical forest. Because the data of direct tree harvest for allometric regression model are difficult to acquire in the field therefore few published studies are available. First published has been studied biomass equations of mixed-deciduous forest of Thailand for converse forest inventory data to biomass by Ogawa et al. (1965) (2), founded that biomass (*B*) is relate with biometric parameter is only D^2H. Chave *et al*. (2005) (1) studied tree biomass equation and methods of improving the estimation of carbon stocks and balance in tropical forests. They founded that models using wood specific gravity, diameter at breast height and height combined (ρD^2H) proved a better fit than models using only diameter at breast height (*D*) and wood specific gravity (ρ). Comparing difference of two biomass equation patterns between

($\ln(B) = c + \beta\ln(D^2H)$ and $\ln(B) = c + \alpha\ln(\rho D^2H)$) in four tree species should be studied leading to an understanding on allometric regression model improving of tree species level of tropical forest.

METHODOLOGY

The trees were selected according to stem size classes of each species. For example, size classes of species 2-30 cm diameter at breast height (dbh) were then set at 2-5 cm, 6-10 cm, 11-20 cm, > 20 cm. In each species, not more than 9 trees, 2 trees per size class, were cut. (19).The damaged tree would not be selected as a sample group each species. Total height (H) was measured after cutting the tree. For each, tree components were separated into four fractions: (1) leaves, (2) branches (D < 6.4 cm), (3) large branches and stems with (D>6.4 cm), (4) basal stem. The stem was weighed after cutting the tree wood specific gravity was determined (3). The tree samples were taken near the Sai Yok 4 hectare research plot but not on the plot so as to not disturb possible future studies. The regression model in each specie will be the standard form for allometric equations: $yi = a(x)^b$, where $yi = B$ is dependent variable, $x = D^2H$ and ρD^2H independent, and a and b are scaling factors. These equations use the fit of a linear regression model [$\ln(y) = a + b\ln(x)$]. The slopes and elevations of the regression models are compared among species and tested by analysis of covariance (4). Comparing simple linear regression equations technique used in case at comparing among regressions of more than two lines by analysis of statistical difference of slope and elevation among regression.

RESULTS AND DISCUSSION

The complex variable between D and H becomes D^2H as the independent variable in linear regression ($\ln(B) = c + \alpha\ln(D^2H)$) has been widely used in Thailand for mixed-species regression (2). It has believed that this is appropriate for estimation of biomass in natural forest. Allometric regression used mixed species for devising the model, although in natural forest did have differences among species. The difference of linear regression in each species found in this study is shown in Table 1.

Table 1 Testing for differences among the four regressions ($\ln(B) = c + \beta\ln(D^2H)$)

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	28.30	27.01	9	1.05	0.5765	7
Millettia brandisiana	12.93	15.77	19.79	8	0.80	0.3624	6
Grewia eriocarpa	21.85	21.53	21.62	8	1.00	0.4014	6
Bridelia ovata	11.93	13.17	15.23	8	0.86	0.5389	6
“Pooled”regression						1.88	25
“Common”regression	76.94	78.77	83.65			2.77	28
“Total”regression	83.50	79.21	83.50	33	0.94	8.61	31

To test for differences between slopes of *Sterculia pexa*, *Millettia brandisiana*, *Grewia eriocarpa* and *Bridelia ovata*:

$H_0 : \beta_1 = \beta_2 = ...\beta_n$ H_A : All these β 's are not equal

$F = \dfrac{(2.77-1.88)/(4-1)}{(1.88/25)}$ = 3.96 Since $F_{0.05(1),3,25}$ = 2.99, reject H_0.

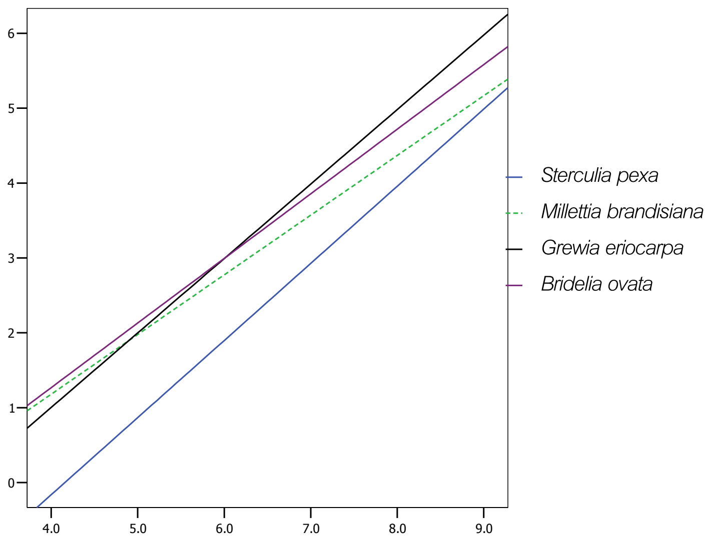

Figure 1 Comparing linear regression lines ($\ln(B) = c + \alpha\ln(D^2H)$) of four species

The results in Table 2 show tests for differences between linear regressions in four tree species. The slopes differ significantly. Comparison of linear regression line ($\ln(B) = c + \beta\ln(D^2H)$) of four species is shown in Figure 1. As Figure 1, slope of linear regression line of *Sterculia pexa* and *Grewia eriocarpa* are similar. Therefore, resemblance mentioned will be determined in Table 2.

Table 2 Testing for difference two regressions ($\ln(B) = c + \beta \ln(D^2 H)$)

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
sterculia pexa	30.23	28.30	27.01	9	1.05	0.5765	7
Millettia brandisiana	12.93	15.77	19.79	8	0.80	0.3624	6

To test for differences between slopes of *Sterculia pexa* and *Millettia brandisiana*:

$H_0 : \beta_1 = \beta_2$ $\quad H_A : \beta_1 \neq \beta_2$

$t = \frac{1.048 - 0.797}{0.079}$ = 3.156 Since $t_{0.05(2),13}$ = 2.16, reject H_0 , $P < 0.050$

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	28.30	27.01	9	1.05	0.5765	7
Grewia eriocarpa	21.85	21.53	21.6	8	1.00	0.4014	6

To test for differences between slopes of *Sterculia pexa* and *Grewia eriocarpa*:

$H_0 : \beta_1 = \beta_2$ $\quad H_A : \beta_1 \neq \beta_2$

$t = \frac{1.05 - 1.00}{0.079}$ = 0.656 Since $t_{0.05(2),13}$ = 2.16, accepted H_0 , $P > 0.05$

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	28.30	27.01	9	1.05	0.5765	7
Bridelia ovata	11.93	13.17	15.23	8	0.86	0.5389	6

To test for differences between slopes of *Sterculia pexa* and *Bridelia ovata*:

$H_0 : \beta_1 = \beta_2$ $\quad H_A : \beta_1 \neq \beta_2$

$t = \frac{1.048 - 0.865}{0.094}$ = 1.950 Since $t_{0.05(2),13}$ = 2.16, accepted H_0 , $P > 0.05$

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Millettia brandisiana	12.93	15.77	19.79	8	0.80	0.3624	6
Grewia eriocarpa	21.85	21.53	21.62	8	1.00	0.4014	6

To test for differences between slopes of *Millettia brandisiana* and *Grewia eriocarpa*:

$H_0 : \beta_1 = \beta_2$ $\quad H_A : \beta_1 \neq \beta_2$

$t = \frac{0.796 - 0.996}{0.078}$ = -2.535 Since $|t|$ = 2.535 > $t_{0.05(2),12}$ = 2.179, reject H_0 , $P < 0.05$

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Millettia brandisiana	12.93	15.77	19.79	8	0.80	0.3624	6
Bridelia ovata	11.93	13.17	15.23	8	0.86	0.5389	6

To test for differences between slopes of *Millettia brandisiana* and *Bridelia ovata*:

$H_0 : \beta_1 = \beta_2$ $\quad H_A : \beta_1 \neq \beta_2$

$t = \frac{0.796 - 0.865}{0.093}$ = -0.727 Since |*t*| = 0.727 < $t_{0.05(2),12}$ = 2.179, reject H_0 , *P* > 0.05

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Grewia eriocarpa	21.85	21.53	21.62	8	1.00	0.4014	6
Bridelia ovata	11.93	13.17	15.23	8	0.86	0.5389	6

To test for differences between slopes of *Grewia eriocarpa* and *Bridelia ovata*:

$H_0 : \beta_1 = \beta_2$ $\quad H_A : \beta_1 \neq \beta_2$

$t = \frac{0.996 - 0.865}{0.094}$ = 1.4 Since $t_{0.05(2),12}$ = 2.179, accepted H_0 , *P* > 0.05

Table 2 shows result of testing for differences of slopes among four linear regressions. There are significant difference between *Sterculia pexa* and *Millettia brandisiana, Millettia brandisiana* and *Grewia eriocarpa*. There are no significant difference between *Sterculia pexa* and *Grewia eriocarpa*, *Sterculia pexa* and *Bridelia ovata, Millettia brandisiana* and *Bridelia ovata, Grewia eriocarpa* and *Bridelia ovata*.

Table 3 Testing of differences among four regressions ($\ln(B) = c + \beta \ln(\rho D^2 H)$)

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	29.37	28.86	9	1.018	0.3474	7
Millettia brandisiana	12.93	17.28	23.73	8	0.73	0.3528	6
Grewia eriocarpa	21.85	22.22	22.83	8	0.97	0.2179	6
Bridelia ovata	11.93	13.99	17.09	8	0.82	0.4833	6
"Pooled" regression						1.40	25
"Common" regression	76.94	82.86	92.51			2.72	28
"Total" regression	83.50	87.48	95.99	33	0.90	3.78	31

To test for differences between slopes of *Sterculia pexa*, *Millettia brandisiana*, *Grewia eriocarpa* and *Bridelia ovata*:

$H_0 : \beta_1 = \beta_2 = ...\beta_n$ H_A : All these β's are not equal

$F = \frac{(1.4 - 0.48)/(4-1)}{(140/25)}$ = 5.464 Since $F_{0.05(1),3,25}$ =2.99, reject H_0.

The results in Table 3 show tests for differences between linear regressions in four tree species. The slopes differ significantly. Comparison of linear regression line ($\ln(B) = c + \beta \ln(\rho D^2 H)$) of four species is shown in Figure 2. As Figure 2, slope of linear regression line of *Sterculia pexa* and *Grewia eriocarpa* are similar. Therefore, resemblance mentioned will be determined in Table 4.

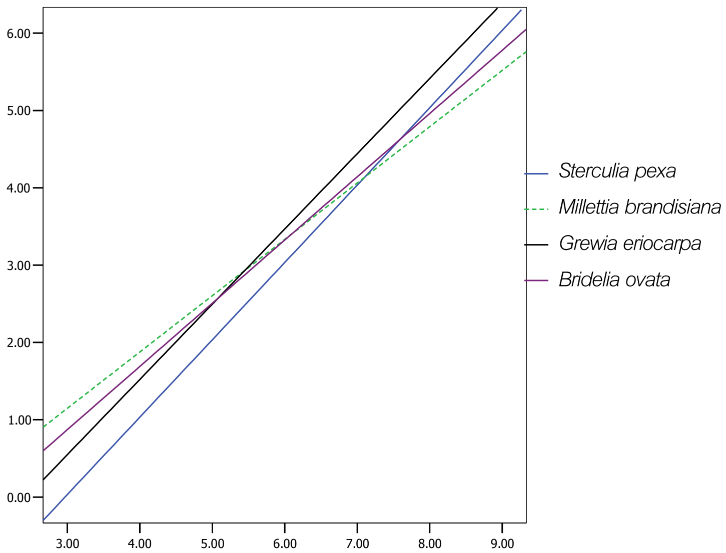

Figure 2 Comparing linear regression lines ($\ln(B) = c + \alpha \ln(\rho D^2 H)$) of four species

Table 4 Testing for difference two regressions ($\ln(B) = c + \beta \ln(\rho D^2 H)$)

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	29.37	28.86	9	1.018	0.3474	7
Millettia brandisiana	12.93	17.28	23.73	8	0.73	0.3528	6

To test for differences between slopes of *Sterculia pexa* and *Millettia brandisiana*:

$H_0 : \beta_1 = \beta_2$ $H_A : \beta_1 \neq \beta_2$

$t = \frac{1.018 - 0.728}{0.064}$ = 4.503 Since $t_{0.05(2),13}$ = 2.16, reject H_0, *P* < 0.050

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	29.37	28.86	9	1.02	0.3474	7
Grewia eriocarpa	21.85	22.22	22.83	8	0.97	0.2179	6

To test for differences between slopes of *Sterculia pexa* and *Grewia eriocarpa*:

$H_0: \beta_1 = \beta_2$ $\quad$ $H_A: \beta_1 \neq \beta_2$

$t = \frac{1.02 - 1.00}{0.059}$ = 0.757 $\quad$ Since $t_{0.05(2),13}$ = 2.16, accepted H_0, *P* > 0.050

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Sterculia pexa	30.23	29.37	28.86	9	.018	0.3474	7
Bridelia ovata	11.93	13.99	17.09	8	0.82	0.4833	6

To test for differences between slopes of *Sterculia pexa* and *Bridelia ovata*:

$H_0: \beta_1 = \beta_2$ $\quad$ $H_A: \beta_1 \neq \beta_2$

$t = \frac{1.018 - 0.818}{0.077}$ = 2.581 $\quad$ Since $t_{0.05(2),13}$ = 2.16, reject H_0, *P* < 0.050

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Millettia brandisiana	12.93	17.28	23.73	8	0.73	0.3528	6
Grewia eriocarpa	21.85	22.22	22.83	8	0.97	0.2179	6

To test for differences between slopes of *Millettia brandisiana* and *Grewia eriocarpa*:

$H_0: \beta_1 = \beta_2$ $\quad$ $H_A: \beta_1 \neq \beta_2$

$t = \frac{0.728 - 0.973}{0.064}$ = -3.838 $\quad$ Since |*t*| = 3.838 > $t_{0.05(2),12}$ = 2.179, reject H_0, *P* < 0.05

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Millettia brandisiana	12.93	17.28	23.73	8	0.73	0.3528	6
Bridelia ovata	11.93	13.99	17.09	8	0.82	0.4833	6

To test for differences between slopes of *Millettia brandisiana* and *Bridelia ovata*:

$H_0: \beta_1 = \beta_2$ $\quad$ $H_A: \beta_1 \neq \beta_2$

$t = \frac{0.728 - 0.818}{0.084}$ = -1.079 $\quad$ Since |*t*| = 1.079> $t_{0.05(2),12}$ = 2.179, accepted H_0, *P* > 0.05

Species	$\sum y^2$	$\sum xy$	$\sum x^2$	n	b	ResidualSS	ResidualDF
Grewia eriocarpa	21.85	22.22	22.83	8	0.97	0.2179	6
Bridelia ovata	11.93	13.99	17.09	8	0.82	0.4833	6

To test for differences between slopes of *Grewia eriocarpa* and *Bridelia ovata*:

$H_0 : \beta_1 = \beta_2$ $\quad$ $H_A : \beta_1 \neq \beta_2$

$t = \frac{0.973 - 0.818}{0.077}$ = 2.004 $\quad$ Since $t_{0.05(2),12}$ = 2.179, accepted H_0, $P > 0.05$

Table 4 shows revaluate of testing for difference of slopes among four linear regressions. There are significant difference between *Sterculia pexa* and *Millettia brandisiana, Sterculia pexa* and *Bridelia ovata, Millettia brandisiana* and *Grewia eriocarpa*. There are no significant difference between*, Sterculia pexa* and *Grewia eriocarpa*, *Millettia brandisiana* and *Bridelia ovata, Grewia eriocarpa* and *Bridelia ovata*.

CONCLUSION

Compare difference of slope among four tree species linear regressions in the first form consists of diameter at breast height and height ($\ln(B) = c + \beta\ln(D^2H)$), and the second form consists of wood specific gravity, diameter at breast height and height ($\ln(B) = c + \alpha\ln(\rho D^2H)$).The linear regression indicated that there are differences of biomass among four trees species. Regression form indicates that the most essential variable for improving species-specific regression is wood specific gravity because its changes depend on species and diameter at breast height of tree (5, 6, 7). Additionally, lights and competition between species also affect the biomass (4, 8).

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