

CHAPTER 2

DETERMINATION OF GENERATED RICE FIELD RESIDUE

2.1 Introduction

Rice field residue is a part of paddy left in the field after the crops are harvested and thrashed. It is a kind of non-woody biomass. The term of rice field residue in this study is referred to rice stubble and straw. Rice field residue is about 52.2% of rice composition which divided into rice straw 21.9% and rice stubble 30.3% [DEDE, 2003]. Rice straw is a part of paddy (rice) which connects to the panicle. Stubble is a root and a part of paddy (rice) which height about 30 cm above ground. Harvest part which removed from the paddy field is rice panicle and a part of rice straw

A factor related to the amount of rice residue in each area is planting method (broadcast/transplant) [Summers, M.D., 2003; PUSTAKA]. The amount of rice seed is about 0.125-0.156 tons/ha for broadcast method while only 0.025-0.0375 tons/ha used for transplant method [Rice Thailand, 2010]. Take into account of residue in unit area, in 30 cm × 30 cm of transplant-paddy field, it has 16 botanical. In case of broadcast, it is unable to count the number of botanical in unit area because of the scattering of seed.

A main factor related to the amount of stubble and straw in each area is harvesting method (machine/human) [Kadam, K. et al.; Summers, M.D., 2003; PUSTAKA]. Machinery harvest, the cutting level is lower than 30 cm (from ground level); it obtains high straw and less stubble. Human harvest, the cutting level is about waist level (about 90 cm from ground level); it gets the high amount of stubble and the low straw.

The amount of residue is normally estimated from the factor as straw to grain ratio (SGR) or residue to product ratio (RPR), harvest index (HI), biomass load (BL). RPR ratio is often used for estimating available straw [Summer, M.D. et al, 2003] that has the range of 0.306 to 1.695 [Arthayukti, W., 1993; DEDE, 1997; EPPO, 1997; SIDA, 1999-2001; Yokoyama, S. et al., 2000; DEDE, 2001; Jungner, M. et al., 2001; DEDE, 2002; Bhattacharya, S.C., et al., 2003; Sajjakulnuikt, B. et al., 2005; Tia, S. et al., 2005; PCD, 2005; EFE, 2006; DEDE and Chiang Mai University, 2006; JGSEE, 2006]. The lowest value (0.306) was reported from DEDE, 2001 and the highest value (1.695) was reported from Yokoyama, S. et al., 2000. The value of RPR from previous study is quiet vary. Most of the result is in term of the overall produced residue. It does not specific for stubble or straw.

From these backgrounds, the study in this part attends to develop the method that can be used to quantify the amount of stubble and straw in Thailand. The estimated method was developed from the relationship between weight and height of rice panicle.

2.2 Methodology

This study assessed the amount of rice stubble and straw based on the data from field survey. The process of field survey is described as followed:

2.2.1 Sampling Method

This study collected rice using random sampling method. Random sampling method is statistical method based on assumption all samples have a same opportunity of selection. This study collected 30 samples of broadcast-major rice, 30 samples of transplant-major rice, 30 samples of broadcast-minor rice, and 30 samples of transplant-minor rice. This study collected 30 samples for each group because 30 samples is the minimum acceptable sampling which enough for data distribution analysis. The number of sample in each area based on the size of paddy field and the fraction of paddy field by planting method that obtained from Office of Agricultural Economic (OAE). The share of paddy field classified by type of rice (major and minor) and planting method (transplant and broadcast) is summarized as shown in Table 2.1. Table 2.2 shows the sampling number of field survey in each region.

Table 2.1 Share of paddy field classified by type of rice and planting method

	% of paddy field			
	Major rice		Minor rice	
	Transplanted	Broadcasting	Transplanted	Broadcasting
Northern	35	65	5	95
Northeastern	60	40	13	87
Central	8	92	1	99
Southern	40	60	13	87

Source: OAE, 2007

Table 2.2 Location of field survey

	Sampling number			
	Major rice		Minor rice	
	Transplanted	Broadcasting	Transplanted	Broadcasting
Northern	7	8	4	5
Northeastern	10	6	5	12
Central	9	13	9	18
Southern	4	3	3	4
Total	30	30	30	30

2.2.2 Data Collection

- 1) To cut 30 samples of transplanted-major rice, 30 samples of broadcasting-major rice, 30 samples of transplanted-minor rice and 30 samples of broadcasting-minor rice at ground level and weight sample in the field.
 - In case of broadcasting method: Collect paddy and measure the weight of residue in area of 1 m × 1 m. So, this stage obtained weight of paddy and weight of residue in 1 m² area.
 - In case of transplanting method, Collect paddy and count the number of paddy in 1 m × 1 m. So, this stage obtained weight of paddy and number of paddy in 1 m² area.
- 2) To divide the rice stalk into sections at 10 cm for each and weight for each section
- 3) To analyze the moisture content of rice stalk by oven at 105 degree Celsius 24 hours (Accordance with ASAE standard S358.1)
- 4) To weight the rice stalk for dried weight
- 5) To analyze the relationship between the weight per unit area and height, this relationship is applied to calculate the amount of rice stalk in unit area and the amount of rice stubble in unit area which computed from harvesting method. The amount of rice straw is obtained by subtracting the amount of rice stalk by amount of rice stubble.

2.2.3 Data Analysis

The data analysis included 2 parts: statistical properties and physical properties of rice plant.

Statistical properties

The statistical analysis included 3 processes: regression analysis, F-test, and T-test. The information of each process is described as follows:

Regression analysis

Regression analysis is a statistical method, used to analyze the relationship between a dependent variable and one or more independent variables. Regression model relates Y to a function of X and β ($Y \approx f(X, \beta)$), where: X is independent variable, β is coefficient, and Y is dependent variable. There are 2 basic types of regression; linear regression (one independent variable explains a dependent variable) and multiple regression (two or more independent variables explain a dependent variable).

This study uses linear regression to analyze the relationship between height and weight of rice stalk using SPSS 15.0. This study uses linear regression because this study considers one independent variable which is height of rice stalk to predict one dependent variable which is weight of rice stalk. The result from this process is the relationship (model) between height and weight of rice stalk and the R^2 value which represented the goodness of fit of the model.

F-test

F-test is a statistical method, used to test the model that has been fit to a data set by comparing the variances of independent variables. It is used to analyze the suitability of the model. F-test considers on sum of square. If the value of F-test higher than the chi-square value, means the model fit for the data. This study uses F-test for checking the overall fit of the model after the regression analysis process.

T-test

T-test is a statistical method, used to test the significance of variables. The hypothesis of T-test is the population mean is equal to a specific value (μ_0). T-test equation is

$$t = \frac{\hat{\beta} - \beta_0}{SE_{\hat{\beta}}}; \text{ where: } \hat{\beta} \text{ is least square estimator, } SE_{\hat{\beta}} \text{ is the standard error of least square}$$

estimator, β_0 is specified value. If t-test is lower than 0.05, means the coefficient of variable is significance. This study uses T-test for checking the significant of individual parameter.

Rice physical of rice plant

Rice has conical shape. When rice panicles are divided into sections and unfolding each section, it has trapezium shape as shown Figure 2.1. The volume of rice panicle in each section is estimated from the area of trapezium and height as the formula:

$$V = \frac{1}{2}(\text{sum of parallel long}) \times \text{height} \times \text{height} .$$

Mass of material is a function of volume as the formula: $m = \rho V$. Based on this information, mass of rice panicle should be in terms of quadratic function.

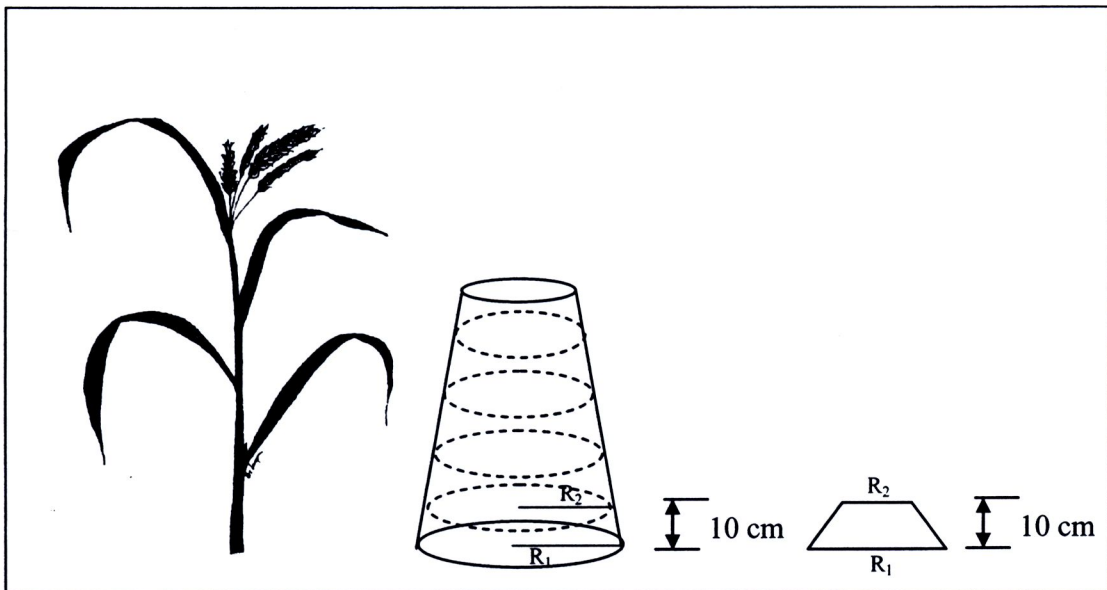


Figure 2.1 Physical and cross section of rice

2.3 Results and Discussion

Field survey provided weight of paddy in unit area for each section, classified by type of rice (major and minor rice) and planting method (transplanted and broadcasting) as shown in Table 2.3.

Table 2.3 Data from field survey

Height (cm)	Weight (g/m ²)			
	Major rice		Minor rice	
	Transplant	Broadcast	Transplant	Broadcast
0-10 (from ground)	109.94	59.43	337.01	306.59
11-20	92.82	86.56	215.49	307.09
21-30	93.03	87.93	153.92	287.46
31-40	86.36	80.56	134.45	251.20
41-50	70.28	64.87	101.23	256.06
51-60	72.02	65.01	177.00	203.11
61-70	64.68	66.04	150.78	201.00
71-80	59.67	64.38	143.05	175.48
81-90	58.24	56.04	152.11	70.59
91-100	46.28	54.17	156.13	73.98
101-110	54.44	90.21		
111-120	37.76	52.32		
121-130	64.19	74.63		

The results show that mass of rice stalk varies on the height. Weight declined while botanical height increased due to physical of rice. This result relates to the study of Summer, M.D. et al. that found mass in each botanical fraction varies on the height [Summer, M.D. et al, 2003].

The relationship between botanical weight and height of each section is applied to assess the amount of overall rice residue and the amount of rice stubble. Rice stubble and rice straw are a part of rice stalk separated by harvesting. Amount of straw is also strongly affected by cutting height [Kadam, K. et al., 2000; Summer, M.D. et al., 2003]. Cutting at ground level will giving maximum of straw. The amount of stubble will increased when increasing of level of cutting. The cutting level equals to the height of botanical. This study estimates amount of straw and stubble from the relationship between cumulative weight and cutting level. The relationship between cumulative weight in unit area and cutting level is analyzed using SPSS 15.0. The result is shown in Table 2.4 for major rice and Table 2-5 for minor rice.

Table 2.4 Relationship between weight in unit area and height of cutting height for major rice**Table 2.4 (a)** Model summary of major rice

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	0.999	0.999	4.237

The independent variable is height.

Table 2.4 (b) ANOVA analysis of major rice

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	584781.469	2	292390.735	16290.004	.000
Residual	143.593	8	17.949		
Total	584925.062	10			

The independent variable is height.

Table 2.4 (c) Coefficients of model of major rice

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Height	9.0539	.138	1.509	72.100	.000
height ** 2	-0.017	.001	-.538	-25.730	.000
(Constant)	16.230	4.166		3.896	.200

The interpretation of the results in Tables 2.4 (a) to 2.4 (c) is summarized as followings.

- From Table 2.4 (a): $R^2 = 0.9988$, it means coefficient of determination is 99.85%. So, the botanical height describes the botanical weight 99.88%.
- From Table 2.4 (b): $F (16290.004) > F_{1, 11, 0.95} (4.84)$, it means the botanical weight has the quadratic relationship with the botanical height.
- From Table 2.4 (c): the relationship between the botanical height and the botanical weight is $y = -0.017x^2 + 9.0539x + 16.230$
- From t-test in Table 2.4 (c): the significance of the coefficients of x^2 (0.000) and x (0.000) is lower than 0.05 so the coefficients of x^2 and x is significance. The significance of the coefficients of constant (0.200) is higher than 0.05 so it is not significant.
- So, botanical weight in unit area as a polynomial function of botanical height of each section for major rice which the formula $y = -0.017x^2 + 9.0539x$ (as shown in Figure 2.2 and Equation 2.1). The formula associates to the physical of rice that the volume of rice is a quadratic function (the information of rice physical is shown in section 2.2.3).

Table 2.5 Relationship between weight in unit area and cutting height for minor rice**Table 2.5 (a)** Model Summary for minor rice

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	.998	.998	26.995

The independent variable is height.

Table 2.5 (b) ANOVA analysis for minor rice

	Sum of Squares	df	Mean Square	F	Sig.
Regression	8275795.159	2	4137897.580	5678.087	.000
Residual	5101.240	7	728.749		
Total	8280896.399	9			

The independent variable is height.

Table 2.5 (c) Coefficients of model for minor rice

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta	B	Std. Error
Height	29.062	1.326	1.586	37.902	.000
height ** 2	-0.0991	.012	-.612	-14.614	.000
(Constant)	226.256	31.751		7.126	.415

The interpretation of the results in Tables 2.5 (a) to 2.5 (c) is summarized in the following.

- From Table 2.5 (a): $R^2 = 0.9979$, it means coefficient of determination is 99.79%. So, the botanical height describes the botanical weight 99.79%.
- From Table 2.5 (b): $F(5678.087) > F_{1, 11, 0.95}(4.84)$, it means the botanical weight has the quadratic relationship with the botanical height.
- From Table 2.5 (c): the relationship between the botanical height and the botanical weight is $y = -0.0991x^2 + 29.062x + 226.256$
- From t-test in Table 2.5 (c): the significance of the coefficients of x^2 (0.00) and x (0.00) is lower than 0.05 so the coefficients of x^2 and x is significance. The significance of the coefficients of constant (0.415) is higher than 0.05 so it is not significant.
- So, botanical weight in unit area as a polynomial function of botanical height of each section for minor rice which the formula $y = -0.0991x^2 + 29.062x$ (as shown in Figure 2.2 and Equation 2.2). The formula associates to the physical of rice that the

volume of rice is a quadratic function (the information of rice physical is shown in section 2.2.3).

$$y = -0.1017x^2 + 9.0539x; (0 \leq x \leq 155) \quad \text{for major rice --- (Equation 2.1)}$$

$$y = -0.0991x^2 + 29.062x; (0 \leq x \leq 120) \quad \text{for minor rice --- (Equation 2.2)}$$

Where: x = cutting level

y = amount of residue in unit area (biomass load)

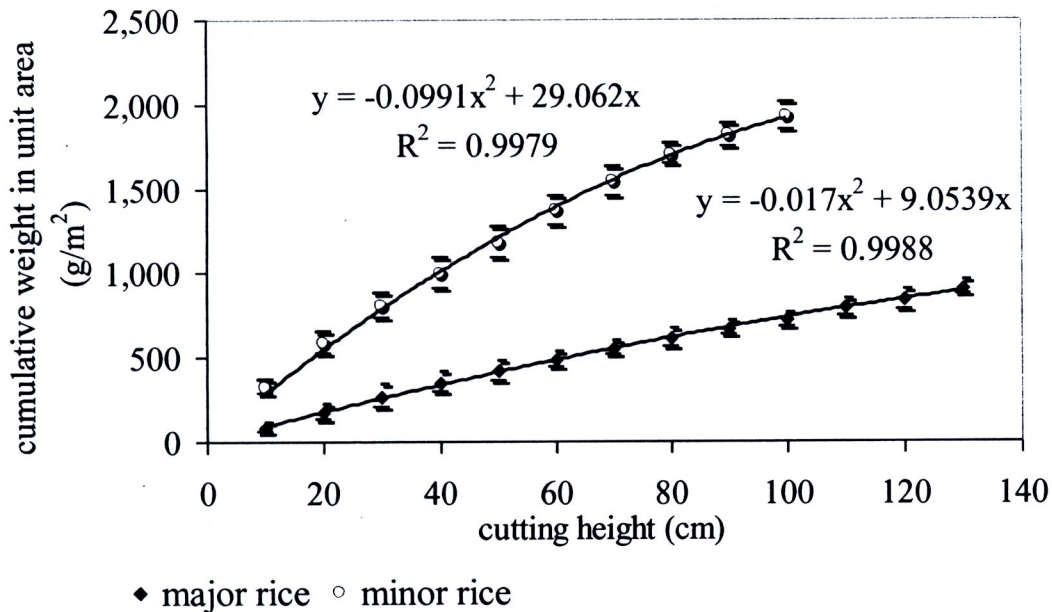


Figure 2.2 Relationship between cutting level and biomass load

These relationships are applied to assess the amount of rice straw and stubble for each area. When applying the height of rice seed into the relationship, it provides the amount of overall residue. When apply the cutting level or cutting method (machine or human) in each area with that relationship, it provides the amount of rice stubble. The average of cutting level is about 30 cm for machine harvest and 90 cm for human harvest. The amount of straw calculates from the difference between amount of overall residue and stubble.

Based on Equation 2.1, at cutting level 30 cm (machinery harvest) and 90 cm (human harvest), the amount of major-stubble are about 256 g/m² and 677 g/m² respectively. At the height of major rice which vary on 140 cm -154 cm [OAE, 2007], the overall amount of

major-residue is between 866 g/m² and 930 g/m². The differential between the amount of residue and stubble is the amount of straw which is about 221-642 g/m². Based on these results and the average of major rice production is about 325 g/m² [OAE, 2007], it associates to 0.79-2.08 of stubble to product ratio (stubble-RPR) and 0.68-1.97 of straw to product ratio (straw-RPR).

Based on Equation 2.2, at cutting level 30 cm (machinery harvest) and 90 cm (human harvest), the amount of minor stubble are about 782 g/m² and 1,812 g/m² respectively. At the height of minor rice which vary on 98 cm -118 cm [OAE, 2007], the overall amount of residue is between 1,896 g/m² and 2,049 g/m². The differential between the amount of residue and stubble is the amount of straw which is about 160-1,190 g/m². Based on these results and the average of minor rice production is about 396 g/m² [OAE, 2007], it associates to 1.98-4.58 of stubble to product ratio (stubble-RPR) and 0.40-3.00 of straw to product ratio (straw-RPR).

From the literature review on biomass load (BL), it was found that the value of BL of Thailand varies on 0.70 kg/m² to 1.90 kg/m² (the information of BL from literature review is shown in Table 2.6). The minimum value of BL (0.70 kg/m²) associates to the value of major-stubble-RPR and the value of major-straw-RPR from this study. The maximum value of BL (1.90 kg/m²) associates to the value of minor-stubble-RPR and the value of minor-straw-RPR from this study.

Table 2.6 Amount of rice field residue per area

Amount of rice field residue per area (kg/m ²)	Year/Place	Source
0.85	1990/Thailand	ONEP, 1990
1.12	1999/California	Summer, M.D. et al, 2003
0.85	2000/California	Summer, M.D. et al, 2003
0.70-1.90	2005/Thailand	PCD, 2005
0.69	2005/California	Hays, M.D., et al, 2005
0.67	2005/US	Hays, M.D., et al, 2005
0.70	2005/Global	Hays, M.D., et al, 2005

According to the literature review on residue to product ratio (RPR) was in the range of 0.306-1.695 (as the information in Table 2.7). The result from this study is quite higher than the RPR from literature review due to the difference of rice production used to estimate RPR.



Table 2.7 Rice per residue ratio (RPR)

RPR	Year/Location	Source
0.452	1990/Thailand (Northeastern)	Jungnger, M. et al, 2001
0.416	1993/Thailand	Arthayukti, W., 1993
0.447	1997/Thailand	DEDE, 1997; EPPO, 1997; SIDA, 1999-2001,
1.695	2000/Thailand	Yokoyama, S. et al, 2000
0.306	2001/Thailand	DEDE, 2001
1.190	2002/Thailand	DEDE, 2002
0.447	2003/Thailand	Bhattacharya, S.C. et al, 2003
0.447	2005/Thailand	Sajakulnuikt, B. et al, 2005
0.450	2005/Thailand	Tia, S. et al, 2005
0.490	2005/Thailand	EFE, 2006
0.750	2005/Thailand	PCD, 2005
0.447	2006/Thailand (Lampang)	DEDE and Chiang Mai University, 2006
0.430-0.750	2006/Thailand	JGSEE, 2006

2.4 Conclusions

This part assessed the amount of rice stubble and straw by applying the relationship between weight and height of botanical rice. This study collected paddy classified by type of rice (major/minor) and planting method (broadcast/transplant) based on random sampling method. Then, analyzed relationship between weight and height in each section of rice botanical using linear regression method, tested goodness of fit of model using F-test, and tested significance of coefficient using T-test. Moreover, this study also tested the consolidation of the model from physical properties of rice plant.

This study found the amount of generated rice field residue depended on the planting method. This is also confirmed by the result of Summers, M.D. and reported of PUSTAKA. The amount of stubble and straw depends on the rice variety and the harvested method; this also confirmed by the result of Kadam, K. et al.; Summers, M.D. 2003; and PUSTAKA.

The independent variable (which is height of rice) had quadratic relationship with the dependent variable (which is weight of rice). This relationship was applied to assess the amount of stubble and straw. Based on the relationship, the height of rice variety used to expect the amount of generated residue, the cutting level used to expect the amount of stubble, and the difference between generated residue and stubble was equal to the amount of straw.

The assessment of amount of stubble and straw by using relationship between weight and height of botanical rice found the amount of major-stubble is between 0.256 kg/m²-0.677 kg/m², amount of major-straw 0.221-0.642 kg/m², amount of minor-stubble 0.783 kg/m² - 1.813 kg/m² and amount of minor-straw 0.160 kg/m² -1.190 kg/m². These values vary on rice seed and harvesting method for each area. When deriving these values to RPR, they associate to 0.79-2.08 of major-stubble to product ratio (major-stubble-RPR), 0.68-1.97 of major-straw to product ratio (major-straw-RPR), 1.98-4.58 of minor-stubble to product ratio (minor-stubble-RPR) and 0.40-3.00 of minor-straw to product ratio (minor-straw-RPR).

These results demonstrate that BL value is more suitable than RPR. RPR is derived from production which quite fluctuates. BL is derived from paddy field area which is quite similar especially in a normal year.