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Influencing of Rice Residue Management Method on GHG Emission from Rice Cultivation

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***Abstract*—**Thailand is one of the world's leaders of rice producers and exporters. Farmers have to increase the rice cultivation frequency for serving the national increasing of export's demand. It leads to an elimination of rice residues by open burning which is the quickest and costless management method. The open burning of rice residue is one of the major causes of air pollutants and greenhouse gas (GHG) emission. Under ASEAN agreement on trans-boundary haze, Thailand set the master plan to mitigate air pollutant emission from open burning of agricultural residues. In this master plan, residues incorporation is promoted as alternative management method to open burning. However, the assessment of both options in term of GHG emission in order to investigate their contribution to long-term global warming is still scarce or inexistent. In this study, a method on rice residues assessment was first developed in order to estimate and compare GHG emissions from rice cultivation under rice residues open burning and the case with incorporation of the same amount of rice residues, using 2006 IPCC guidelines for emission estimation and Life Cycle Analysis technique. The emission from rice cultivation in different preparing area practice was also discussed.

***Keywords*—**Greenhouse gases, Incorporation, Rice cultivation, Rice field residue, Rice residue management

I. Introduction

Rice residue burning is one of the rice residue management methods which commonly found in many countries as China, India, Philippine, and also Thailand [1-2]. The burning of rice residue is a part of agricultural residue burning activity which emits GHG emissions as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), pollutants as carbon monoxide (CO), particulate matter (PM), and toxic as polycyclic aromatic hydrocarbons (PAHs) [3-4] due to the incomplete combustion process. These also affects to human health. The violent of emission related on the type, amount and moisture content of burned residue, the burned manner (head fire/ backing fire / strip light fire), and the emission factor.

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According to the influencing of biomass burning on human health, biomass burning becomes a main issue in many countries. There are 2 main methods that proposed for open burning emission mitigation; on-farm non-burning as incorporation and off-farm non-burning as energy conversion, construction, mushroom plantation and so on [5]. One of the methods that widely used in many countries is incorporation [2, 5-7].Thailand is one of the countries that normally use open burning for rice residue removal. The annual GHG emission from rice residue open burning in Thailand is in the range of 12,274-43,693 Gg CO_{2eq} [2, 6, 8-9] or about 2% of GHG emission from agricultural activity [9]. Incorporation of rice residue is the way that proposed by Pollution Control Department for reducing open burning emission [10].

Incorporation of rice residue into the soil is safe eco-friendly practice without any adverse effect on crop yield, and it gradually improves soil organic carbon, phosphorus and potassium contents [11] but it leads to some problems as higher cost (compare to burning), increase weed carryover, difficulty of tillage, and increased GHG emission due to flooding while rice cultivation [12]. Moreover, limitation of incorporation is one of the emission mitigation from rice cultivation [13].Based on the conflict of the emission mitigation of rice residue management between burning and incorporation, it leads to the objective of this study which is to study the affect of emission from rice cultivation activity due to the different of rice residue management method. The GHG emission from activity during the pre-cultivation season until pre-harvesting season is estimated by using 2006 IPCC guideline method and compared in different management method.

II. Methodology

To compare the affects of rice residue management on the GHG emission from rice cultivation, GHG emissions from activity during the pre-cultivation season until pre-harvesting season is estimated. During pre-cultivation season, there are 2 main activities that contributed GHG emissions: 1) the residue management activity (burning or non-burning), and 2) the preparing area (2-3 times of tillage; primary tillage, secondary tillage, and tertiary tillage) activity. During pre-harvesting season, GHG emissions are emitted due to anaerobic decomposition of organic material [14]. Based on each activity, a factor that related on amount of GHG emission is amount of rice residue that left in the field. The amount of rice residue has direct effect on the emission from burning and also effect on the difficulty of tillage that will be related on amount of fuel consumption. Moreover, rice residue is a kind of organic carbon which influencing on the CH_4 contribution in rice cultivation. In order to estimate the amount of emission from harvest-season till the rice cultivation, the exact amount of rice managed residue is considered. The amount of rice residue impacts on the open burning emission and the tillage difficulty as well. The tillage difficulty has an effect on the amount of fuel consumption and directly effects on the GHG emission contribution. Moreover, rice residue is an organic carbon that enhances CH_4 contribution from rice cultivation. In order to estimate the exact amount of emission from after harvest-season till the rice cultivation in the next season, the amount of rice residue should be considered. This study starts from the determination of the managed rice residue. The managed rice residue equals to the rice residue that subjected to burning in the field. Then, estimate GHG emission from the activity after harvest-season till the pre- cultivation season. Finally, 2 options of rice residue management are developed: burning-treatment option and non-burning treatment option and compares GHG emission. The structure of each option is shown in Fig. 1.

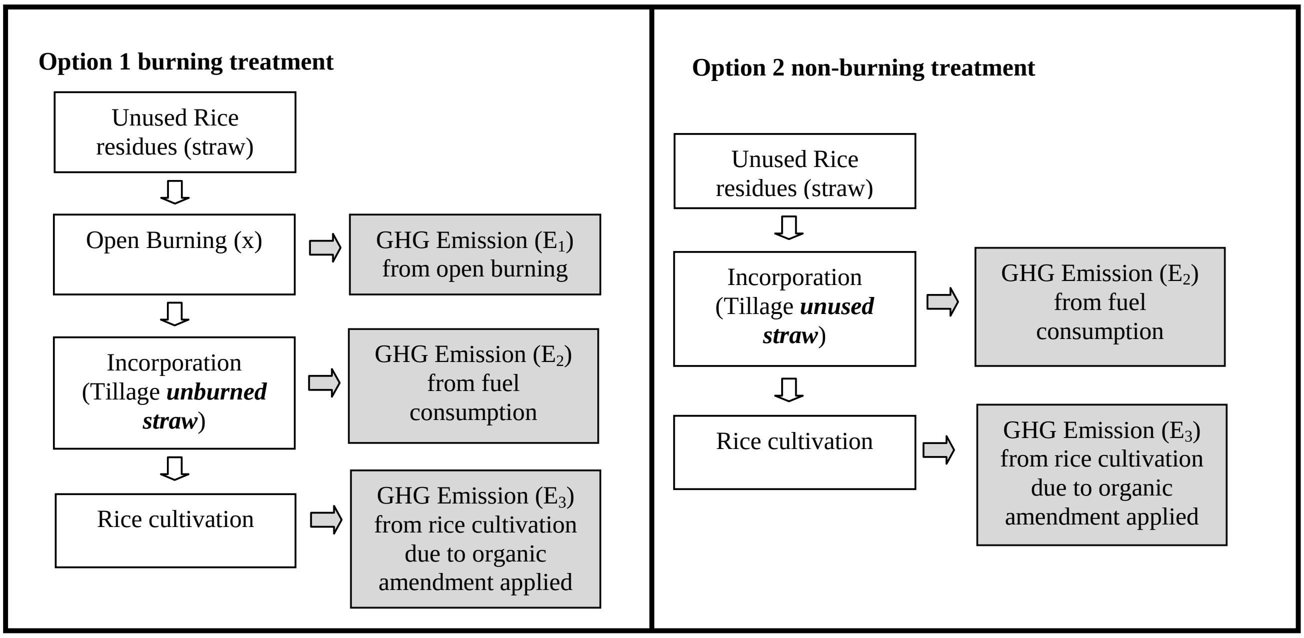

Fig. 1 Emission estimation structure

A. Managed rice residue determination

The managed rice residue is the unused residue, left in the field, and eliminated by burning. These assesses through the amount of generated rice residue and the amount of utilized rice residue. The generated rice residue determines from the rice residue assessment model. The utilized rice residue is estimated through the fraction of utilized residue which obtained from questionnaire survey information.

a. Generated rice residue determination

The generated rice residue composts of stubble and straw. Rice stubble and rice straw are a part of rice stalk that separated by harvest. The amount of rice residue generates in unit area depends on rice varieties, planting method (broadcast: 94-150 kg/ha of rice seed is used/transplant: 25-44 kg/ha of rice seed is used [15], and harvested method (human: cutting level at 90 cm above ground/machine: cutting level at 30 cm above ground). Amount of stubble and straw is strongly affected by cutting height [12, 16]. Cutting at ground level will giving maximum of straw. The amount of stubble will increased when increasing of level of cutting. Based on these information, the rice residue determination model is developed to assess the amount of stubble and straw in each region.

Rice residue determination model development

The rice residue determination model is developed from the assessment the relationship between weight and height of rice stalk. 120 rice sample plots which 1 m^2 size are collected from 20 provinces, comprising 30 plots of transplanted-major rice field, 30 plots of broadcast-major rice field, 30 plots of transplanted-minor rice field, and 30 plots of broadcast-minor rice field. 30 samples are the least of sample number that acceptable in statistical method. Rice is collected at the ground level, separated a part of grain and stalk, and measured for weight of grain and stalk. Dividing stalk into section, 10 cm for each section, measured for each section weight. Then estimate for dried weight by accordance with ASAE standard S358.1. Finally density of the residue in each level and the stalk level is analyzed by using linear regression analysis. The relationship is also tested F-test for the fit of the model, and tested T-test for the significance of the variable.

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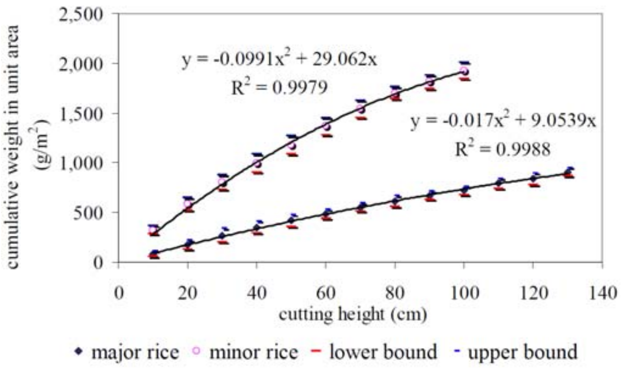

Fig. 2 Rice residue determination models

The rice residue determination model as shown in fig. 2 is applied to assess the amount of stubble and straw in each area through the rice varieties and the harvest method in each area. The rice varieties information is reported by Office of Agricultural Economic (OAE) annually. The harvest method information obtained from questionnaire survey information (question number 5). When apply the rice varieties to the model (140-154 cm represented for the major rice varieties and 98-118 cm represented for the minor rice varieties), the result will present to the density of the residue which is in the range of 866 g/m^2 to 930 g/m^2 for major rice residue and in the range of 1,896 g/m^2 and 2,049 g/m^2 for minor rice residue. When apply the harvest method (90 cm represented for human method and 30 cm represented for machine method) into the model, the result will present to the density of the stubble which is about 677 g/m^2 and 256 g/m^2 for major rice-human harvest and major rice-machine harvest respectively and about 1,812 g/m^2 and 782 g/m^2 for minor rice-human harvest and minor rice-machine harvest respectively. The different between the density of residue and stubble is the value of density of straw. The amount of major straw varies in the rage of 189 g/m^2 to 674 g/m^2. The amount of minor straw varies in the rage of 84 g/m^2 to 1,267 g/m^2.

b.Utilized rice residue determination

Utilized rice residue is rice residue that used for some purpose as animal feeding, mushroom plantation, and so on. The amount of utilized rice residue is estimated from the questionnaire information. The questionnaire survey is conducted with the objective to investigate the percentage of area burned, the mass of fuel available for burning and the combustion factor. Survey question related to this study is shown in table I. 972 farmers were interviewed during 2007 to 2008. The number of questionnaire survey calculated based on rank set sampling method, at 5% proportional error and 95% confident level. Rank set sampling method is a statistical technique for data collection based on simple random sampling that generally leads to more efficient estimators [17-18]. The distribution of the site survey obtained from the interpretation of fire hot spot (FHS) detected by Moderate-resolution imaging spectroradiometer (MODIS) sensor aboard the Terra and Aqua satellites and land use map (the example of FHS detected on paddy field is shown in fig. 3). The site survey included 5 provinces in the Northern; Nakornsawan, Petchchabun, Pitchsanulok, Lampang, and Chiengmai, 6 provinces in the North-eastern; Khnongkai, Surin, Konkaen, Buriram, Mahasarakam, and Nakornratchasrima, 5 provinces in the Central; Chainat, Petchburi, Ratchaburi, Chachoengsao, and Suphanburi, and 4 provinces in the Southern; Chumporn, Nakornratchasrima, Pattalung, and Songkla (the location of questionnaire survey is shown in the fig. 4).

TABLE I
A PART OF QUESTION IN QUESTIONNAIRE SURVEY FOR THIS STUDY

1. What is the size of your paddy field?
2. How frequency does you usually plant rice in the area?
3. What is your water resource? (Irrigation / Rain fed)
4. What is the rice variety that you planted?
5. What is the harvest method that you used? (machine/human)
6. Do you burn your paddy field? If yes, how much of the area burned?
7. Do you use the rice stubble for any purpose? If yes, how much does it used?
8. Do you use the rice straw for any purpose? If yes, how much does it used?
9. Do you burn the rice residue in your area? If yes, what is the purpose of the burning? When and how much does it burned?
10. Which picture represents as the characteristic of your residue and area after burned?

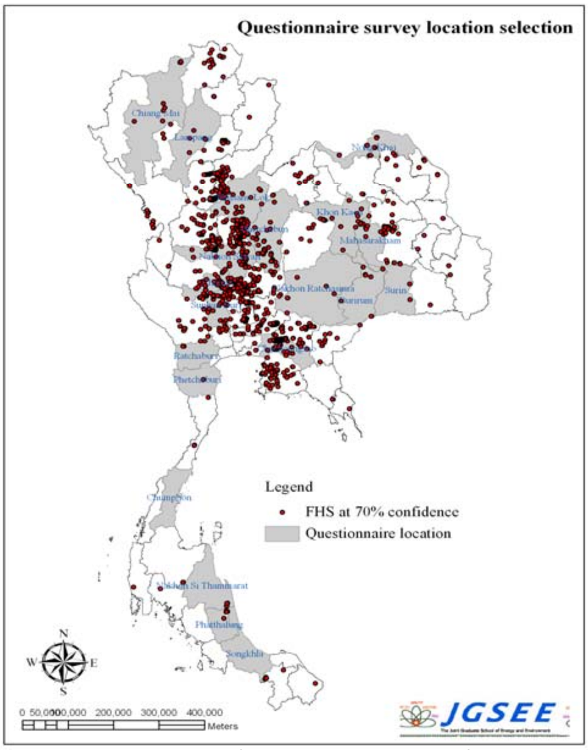

Fig. 3 Example of FHS detected on paddy field

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c. Unused rice residue determination

The unused rice residue in this study means the rice residue that subjected to open burning which is estimated from the production between the fraction of burned area (obtained from questionnaire data) and the different of generated and utilized rice residue (different between result from section 1 and section 2).

B. Emission estimation

a. Emission from burning of rice residue

Based on [14], the emission from burning of rice residue can be estimated using equation 1.

$$L_{fire} \quad = \quad R_B \times EF \times 10^{-3} \qquad (1)$$

Where: L_{fire} (Mg) is the amount of emission from burning of rice residue; R_B (Mg) is the amount of rice residue that burned in the field; EF (g kg^{-1} dm) is emission factor.

Amount of burned rice residue (R_B)

The amount of open burning of rice residue is the amount of unused residue that consumed by fire which estimates through the unused rice residue (result from section 2.1.3) and combustion efficiency (CE). The value of CE obtained from questionnaire survey information.

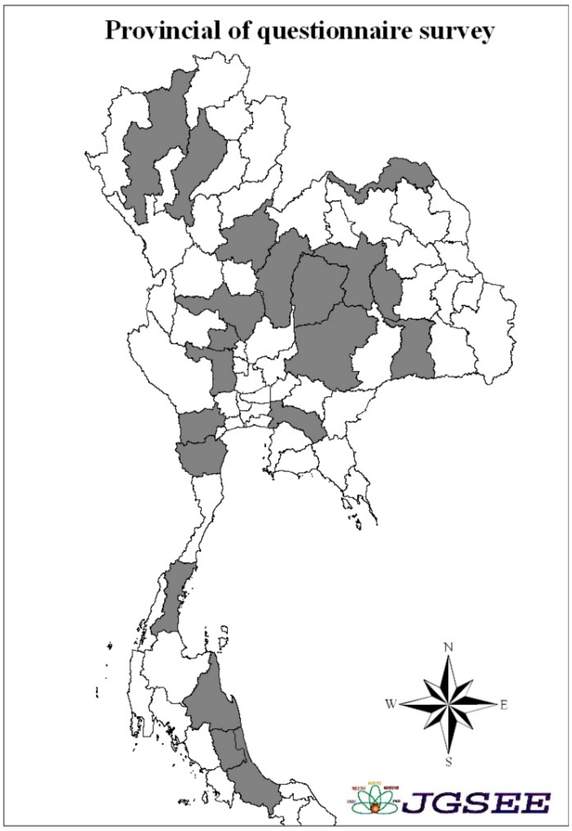

Fig. 4 Location of questionnaire survey

Emission factor (EF)

The EF of CO_2, CO, CH_4, N_2O, NO_x, $PM_{2.5}$, PM_{10}, and BC mostly specific for rice residue open burning are presented in the table II.

TABLE II
DEFAULT VALUE OF EMISSION FACTOR FOR RICE RESIDUE OPEN BURNING

	G_{ef} (g kg^{-1} dm)	Source
CO_2	1,185	[19]
CO	133.2	[19]
CH_4	2.7	[20]
N_2O	0.07	[20]
NO_x	3.1	[16]
$PM_{2.5}$	27.63	[19]
PM_{10}	13	[20]
Black carbon	0.69	[20]

b. Emission from tillage rice residue

Based on [14], the emission from off road transportation can be estimated using equation 2

$$Emissions \quad = \quad \sum_j \left(Fuel_j \times EF_j \right) \qquad (2)$$

Where: emissions (kg) is emissions from off road transportation; $Fuel_j$ (TJ) is fuel consumed; EF (kg TJ^{-1}) is emission factor; and j is fuel type.

Fuel consumed (Fuel)

Fuel requirement of tillage related on paddy field type (irrigated/rain fed), amount of surface residue, and tractor type [21]. The amount of fuel consumed represented in term of energy consumption in unit of paddy field.

Type of paddy field affects to the amount of energy consumed due to the difficulty tillage. According to the study of Chamsing, A., et al. (2006) that studied on the energy consumption for rice cultivation found the energy input in pre-cultivation process for irrigated field is about 27 times of energy input in rain fed field (in the same pre-cultivation pattern).

Density of surface residue influences the tillage efficiency. According to the study of Liu, J. et al. (2010), a part of this study report that studied on the relationship between the amount of residue before and after tillage at difference speed [22]. Based on this study, it is applied to assess the tillage efficiency when incorporated and non-incorporated rice straw. From the assessment found under the same speed, the tillage efficiency in case of incorporated rice straw will be reduced 13% from tillage efficiency of incorporated rice straw.

The amount of energy consumed in tractor depends on engine power. There are 2 main types on tractor that used for tillage process in Thailand: power tiller and tractor 45 hp. Power tiller is mainly used in the field that less than 0.8 ha, at rate 26.25 L/ha of diesel consumption (heating value 47.78 MJ/L). Tractor is widely used in the large field (larger than

0.8 ha) at rate 41.87 L/ha of diesel consumption (heating value 47.78 MJ/L).

Emission factor (EF)

The EF of CO_2, CH_4, and N_2O, for off-road agriculture using diesel are presented in table III.

TABLE III
DEFAULT VALUE OF EMISSION FACTOR FOR OFF-ROAD AGRICULTURE

	EF (kg TJ^{-1})	Source
CO_2	74,100	[23]
CH_4	4.15	[23]
N_2O	28.6	[23]

c. Emission from rice cultivation

Based on [14], the emission from rice cultivation can be estimated using equation 3.

$$CH_4 = \sum_{i,j,k}\left(t_{i,j,k} \times A_{i,j,k} \times EF_{i,j,k} \times 10^{-6}\right) \quad (3)$$

Where: CH_4 (Gg CH_4 yr^{-1}) is annual methane emissions from rice cultivation; $EF_{i,j,k}$ (kg CH_4 $ha^{-1}day^{-1}$) is a daily emission factor for i, j, and k conditions; $t_{i,j,k}$ (day) is cultivation period of rice for i, j, and k conditions; $A_{i,j,k}$ (ha yr^{-1}) is annual cultivated area of rice for i, j, and k conditions; i, j, k represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary.

Cultivation period (t)

The period of cultivation depends on type of rice seed that used in each area. This data obtained from questionnaire survey. The period of cultivation of each area is between 92 and 120 days for major rice and between 115 and 140 days for minor rice.

Cultivation area (A)

The cultivated area in this study is the area that rice residue is incorporated into the soil. This study assumes the cultivated area is the paddy field area that opens burning which assessed from questionnaire information. From the questionnaire information found 36% of major rice area or 2.6 Mha and 65% of minor rice area or 1.3 Mha burn rice residues in the field.

Daily emission factor (EF_i)

The daily emission factor of rice cultivation depends on condition of rice cultivation as rice ecosystem type, flooding pattern before and during cultivation period, and type and amount of organic amendments. The base line of daily emission factor should be adjusted for each condition of rice cultivation by using equation 4.

$$EF_i = EF_c \times SF_w \times SF_p \times SF_o \quad (4)$$

Where: EF_c (kg CH_4 $ha^{-1}day^{-1}$) is baseline emission factor for continuously flooded fields without organic amendments; SF_w (dimensionless) is scaling factor to account for the differences in water regime during cultivation period; SF_p (dimensionless) is scaling factor to account for the differences in water regime in the pre-season before the cultivation period; and SF_o (dimensionless) is scaling factor to account for organic amendment applied.

To adjust the baseline emission due to application of organic amendment, it needs to consider the amount and type of amendment by using equation 5.

$$SF_o = \left(1 + \sum_i ROA_i \times CFOA_i\right)^{0.59} \quad (5)$$

Where: ROA_i (tons ha^{-1}) is application rate of organic amendment i, in the dry weight for straw and fresh weight for other; $CFOA_i$ (dimensionless) is conversion factor for organic amendment i.

Rice straw is an organic carbon. In case of burning of rice residue management, the amount of rice residue that incorporated into soil is neglect due to it is considered in the base line of emission factor. In case of incorporation of rice residue management, the amount of rice residue that incorporated into soil is the amount of unused rice residue that left in the field.

Regarding to equation 4 and 5, the aggregate default values presented in 2006 IPCC Guideline of related factor for adjustment of emission factor of rice cultivation are used in this study. The related factor is summarized as shown in table IV.

TABLE IV
DEFAULT VALUE OF EMISSION FACTOR FOR RICE CULTIVATION ADJUSTMENT

Factor	Condition	Coefficient
Emission factor (base line)		
EF_c (kg CH_4 ha^{-1} day^{-1})	continuously flooded fields without organic amendments	1.30
Scaling factor to account for the differences in water regime during cultivation period		
SF_w	Irrigated	0.78
	Rain fed	0.27
Scaling factor to account for the differences in water regime in the pre-season before the cultivation period		
SF_P	Flood/non-flood	1.22
Scaling factor to account for organic amendment applied		
CFOA	Compost	0.05
	Rice straw (Incorporated > 30 days)	0.29
	Rice straw (Incorporated < 30 days)	1.00
ROA (Mg ha^{-1})	Compost	3.125
	Rice straw (unused rice straw incorporation)	15.50
	Rice straw (unburned rice straw incorporation)	4.60

III. RESULTS

A. Rice residue management

a. Generated rice residue

Regarding to the applying rice varieties and harvested method in each area on the rice residue determination model found the overall amount of rice residue (included straw and stubble) generated during rice cultivation season 2007/2008 is about 117.7 Tg which included 46.3 Tg of stubble-major rice, 36.4 Tg of straw-major rice, 17.2 Tg of stubble-minor rice, and 21.9 Tg of straw-minor rice. These results demonstrate the amount of major rice residue is about 2.1 times of minor rice residue due to the higher amount of cultivated area of major rice (the major rice area is about 4.3 times of minor rice area). Moreover, the major rice varieties, the overall height is in the range between 140 and 154 cm which higher than the height of minor rice varieties (98-119 cm), so the quantity of major rice residue is more than minor rice residue.

Take into consideration on the amount of generated rice residue by residue type found in case of major rice residue, the amount of stubble is higher than straw whereas inverse result for minor rice residue. These is because of the largest of major rice cultivation is in the north-eastern part of Thailand (58% of major rice field) which mainly harvest by human. Normally, the cutting level of human harvest is at the farmer waist level (about 90 cm above ground) which the larger amount of stubble generated than straw. For minor rice, the largest of minor rice area is in the central part of Thailand (53% of minor rice field) which mainly harvest by machine. Moreover, most of minor rice is harvested by machine due to spending less time. The cutting level of machine harvest is only about 30 cm above ground so the smaller amount of stubble generated than straw.

b. Managed rice residue

Regarding to the amount of stubble and straw and the utilization of rice residue information (from questionnaire survey) found 26% of rice residue (30.8±7.5 Tg) is subjected to burned which include 7.8±1.9 Tg of stubble-major rice 3.9±0.96 Tg of straw-major, 9.0±2.18 Tg of stubble-minor rice, and 10.0±2.42 Tg of straw-minor. These results demonstrate main of the rice residue that subjected to burned in the field is minor rice residue. The amount of burned minor rice residue is about 1.6 times of burned major rice residue due to the rush of next rice season. Take into consideration on the subjected to burning of residue by residue type found in case of major rice residue, most of residue that left in the field is stubble which is about 2 times of straw because of the difficulty of utilized stubble. In case of minor rice residue, the amount of stubble closes to the amount of straw. The limitation of time is the cause of the large amount of minor rice residue is left in the field and managed by burning.

After burning, about 19.4±5.28 of rice residue is not consumed by fire which included 6.2±1.6 Tg of stubble-major rice, 1.3±0.5 Tg of straw-major rice, 7.9±1.97 Tg of stubble-minor rice, and 4.0±1.19 Tg of straw-minor rice. Take into consideration on the type of rice residue that burned found the amount of straw is consumed by fire more than stubble because the moisture content of straw is lower than stubble. Another reason related on the farmer behavior, farmer always starts a fire at the driest of straw.

B. Emission from rice cultivation after burning of rice residue

After harvest-season till the rice cultivation in the next season, to manage rice residue by burning method, it consists of 3 main sources of emission: burning of rice residue (from residue management), tillage (soil preparation), and rice cultivation. These activities contribute total GHG emissions about 12.0 Tg which exclude CO_2 from burning of rice residue (as seen in table V). The information of emission contributed from each activity is shown in the following.

TABLE V
GHG EMISSION AFTER HARVEST-SEASON TILL PRE-HARVEST SEASON IN CASE OF RICE RESIDUE BURNING MANAGEMENT

GHG emission	Unit	Activity		
		Burning	Tillage	Rice cultivation
CO_2	Tg CO_2	13.35	0.64	0.00
CH_4	Gg CH_4	30.00	0.04	500
N_2O	Gg N_2O	0.80	0.25	0.00
CO_{2eq}	Tg CO_{2eq}	0.88[a]	0.72	10.40

Remark: a excluded neutral CO_2

a. Emission from burning of rice residue

Only about 11.3±2.2 Tg of rice residue is combusted from the burning of 30.8±7.5 Tg of unused rice residue (CE 0.43). This activity emits 14.2 TgCO_{2eq} of GHG emission included 13.3 TgCO_{2eq} of CO_2 (GWP = 1), 0.03 TgCO_{2eq} of CH_4 (GWP = 21), and 0.8 GgCO_{2eq} of N_2O (GWP 310). The GHG emission and pollutant contributes from the burning of rice residue in the field is tabulated as shown in table VI.

TABLE VI
GHG EMISSION AND POLLUTANT CONTRIBUTES FROM THE BURNING OF RICE RESIDUE IN THE FIELD

	GHG (Tg)		Pollutant (Tg)
CO_{2eq}[a]	3.11	CO	1.50
CO2	13.35	NOx	0.03
CH4	0.03	PM2.5	0.31
N2O	8.0E-04	PM10	1.0E-01
		BC	8.0E-03

Remark: a excluded neutral CO_2

b. Emission from tillage

After burning rice residue, the amount of residue that incorporate in to soil is decreased to 19.5±5.3 Tg. When incorporate this residue into 3.92 Mha of paddy field (2.70 Mha in irrigated area and 1.22 Mha in rain fed area) in the pre-cultivation season, it requires diesel about 182 Ml. The GHG mission contributes from tillage activity contributes about 0.72 Tg CO_{2eq} included 0.64 TgCO_{2eq} of CO_2 (GWP =

1), 0.04 $GgCO_{2eq}$ of CH_4 (GWP = 21), and 0.25 $GgCO_{2eq}$ of N_2O (GWP 310).

c. Emission from rice cultivation

The amount of residue that left after burning is about 19.5±5.3 Tg. This residue is incorporated into soil in the pre-cultivation season. When cultivated rice in the area, it will be contributes 0.5 Tg of CH_4 or about 10.4 $TgCO_{2eq}$ (GWP 21).

Based on 25.4 $TgCO_{2eq}$ of GHG contributed during pre-cultivation (burned rice residue management) till cultivation found the largest of GHG emission included CO_2 emitted from burning of rice residue activity (56% of overall emission), followed by rice cultivation activity (41% of overall emission), and tillage activity (3% of overall emission).

Under the assumption of emission from biomass burning in 2006 IPCC guideline, CO_2 emission from biomass burning is assumed to be reabsorb by the plant in the next cultivation. Based on this assumption, about 86.6% of overall emission is emitted from rice cultivation activity. Burning and tillage activity have similar amount of GHG emission contribution which about 7.4% and 6.0% of overall emission respectively.

C. Emission from rice cultivation after incorporation (non-burning) of rice residue

After harvest-season till the rice cultivation in the next season, to manage rice residue by incorporation method, it consists of 2 main sources of emission: tillage, and rice cultivation. These activities contribute total GHG emission about 15.8 Tg (as seen in table 7). The information of emission contributed from each activity is shown in the following.

TABLE VII
GHG EMISSION AFTER HARVEST-SEASON TILL PRE-HARVEST SEASON IN CASE OF RICE RESIDUE INCORPORATION MANAGEMENT

GHG emission	Unit	Activity	
		Tillage	Rice cultivation
CO_2	Tg CO_2	0.73	0.00
CH_4	Gg CH_4	0.04	700.00
N_2O	Gg N_2O	0.28	0.00
CO_{2eq}	Tg CO_{2eq}	0.82	15.00

a. Emission from tillage

To incorporate 30.8±7.5 Tg of residue into 3.92 Mha of paddy field (2.70 Mha in irrigated area and 1.22 Mha in rain fed area) in the pre-cultivation season, it requires diesel about 206 Ml. The GHG mission contributes from tillage activity contributes about 0.82 Tg CO_{2eq} included 0.73 $TgCO_{2eq}$ of CO_2 (GWP = 1), 0.04 $GgCO_{2eq}$ of CH_4 (GWP = 21), and 0.28 $GgCO_{2eq}$ of N_2O (GWP 310).

b. Emission from rice cultivation

Organic amendment incorporated into soil effects to amount of CH_4 from rice cultivation. Rice straw is a kind of endogenous organic amendment [IPCC, 2006]. When incorporate 30.8±7.5 Tg of residue into soil in the pre-cultivation season which more than 30 days before cultivation in the rain fed area and less than 30 days before cultivation in the irrigated area contributes 0.7 Tg of CH_4 or about 15.0 $TgCO_{2eq}$ (GWP 21).

Based on 15.8 $TgCO_{2eq}$ of GHG contributed during pre-cultivation (incorporated rice residue management) till cultivation found the largest of GHG emission emitted from rice cultivation activity (94.8% of overall emission). Only 5.2% of emission comes from preparing area (tillage process).

D. Comparing of emission in pre-cultivation season till pre-harvest season in different residue management method

After harvest season till rice cultivation of the next season, the GHG emission is contributed from 3 main activities: residue treatment (burning/non-burning), tillage, and rice cultivation. The different residue management method affects to the GHG emission from each activity. In case of burning residue treatment, the overall emission (pre-cultivation to pre-harvest and excluded CO_2 from residue burning) is about 12.0 $TgCO_{2eq}$ whereas 15.8 $TgCO_{2eq}$ emitted from non-burning treatment. These results demonstrate, the GHG emission after harvest season till rice cultivation season of the next season, burning of residue can decreased GHG emission about 39.1% of overall GHG emission from non-burning treatment. Comparing on the emission in pre-cultivation season for preparing area which include residue treatment activity and tillage activity between burning and non-burning residue treatment found burning-treatment in the pre-cultivation season emits 1.59 $TgCO_{2eq}$ (exclude CO_2 from rice residue burning) whereas non-burning treatment emits 0.82 $TgCO_{2eq}$. It demonstrate, in non-burning treatment contributes lower amount of GHG emission than burning treatment about 48.4% because open burning rice residue contributes higher GHG emission than the fuel combustion in the engine. Take into consideration on emission from rice cultivation (pre-harvest season) found emission from rice cultivation after burning of rice residue is about 10.4 $TgCO_{2eq}$ whereas non-burning treatment is about 15.0 $TgCO_{2eq}$. These results demonstrate under the same pattern of rice cultivation, incorporation of rice residue results to the increasing of GHG emission contribution from rice cultivation due to increasing of the decomposition of organic matter. When decreased a unit of incorporated rice residue can reduce 23% of CH_4 from rice cultivation.It can be seen from these results that the rice residue amount and treatment method affects to overall amount of GHG emission from rice cultivation practice. The different treatment method influences on the emission in each rice cultivation process due to the difference amount of residue that left after treatment. Burning-treatment is a way to reduced residue quantity that can reduce GHG emission contribution due to tillage in pre-cultivation season and also reducing GHG emission from rice cultivation. Incorporation-treatment is the cause of the increasing of organic into the soil that high GHG emission will be emitted because the more difficulty and more number of tillage. The rice residue incorporated also increases GHG emission due to enhancement of the organic decomposition.

IV. Conclusion

Rice residue is quantified through the applied of rice residue determination model and rice varieties that planted in rice cultivation season 2007/2008. The questionnaire information is used to assess the amount of unused rice residue that left in the field. During pre-cultivation season till cultivation season, there are 3 main sources of GHG emission: residue treatment (burning/non-burning) activity, tillage activity, and rice cultivation activity. GHG emission in each activity is estimated and compared between residue burning treatment and non-burning treatment by using 2006 IPCC guideline method.

In the season 2007/2008 of rice cultivation in Thailand, about 117.7 Tg of rice residue (straw and stubble) is generated in the field. 26% of this residue is the unused residue that left in the field. After harvest season till the rice cultivation of the next season, there are 3 main activities which are the source of GHG emission: residue treatment (burning/non-burning), tillage, and rice cultivation. Comparing on GHG emission during pre-cultivation season to cultivation season between burning and non-burning treatment found GHG from burning treatment is less than non-burning treatment about 39%. It can be seen that, although incorporation rice residue (non-burning treatment) is a way to mitigate emission from burning residue, it affects to the increasing of GHG emission contribution from the other rice cultivation activities.

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