

CHAPTER 3

RICE FIELD RESIDUE MANAGEMENT

3.1 Introduction

After rice cultivation season, rice field residue as stubble and straw is managed by difference method. The alternatives of residue management are incorporating residue into the soil through tillage, removing and using as mushroom plantation, animal feed, and organic fertilizer, commercial as sale for making commercial product, and leaving and burning in the field [Devendra, C., 1996; DEDE, 2003; Chen Y., et al., 2005, Asia Biobusiness Pte, Ltd, 2006; Gadde, B., 2009]

Regarding the literature review on the management of agricultural residue, the research on agricultural residue management can be divided by purpose of the research into 2 groups; 1) focusing on characteristic of utilization of residue through questionnaire survey [Garivait, S. et al., 2005] and 2) focusing on characteristic of burning of residue through questionnaire survey and satellite data [Garivait, S. et al., 2005; Smith, R., et al., 2007]. Comparing on the burning area between questionnaire survey data and satellite data found the satellite data provides the lower estimation than questionnaire survey data because of the limitation of satellite data as inconsistent between times that satellite overpass and time of field burning.

This part attends to the study of the management of rice stubble and straw using questionnaire surveys that lead to the assessment of open burning rice residue and estimation of emissions from burning.

3.2 Methodology

This study uses questionnaire surveys to study the management of rice field residues. The process is shown in the following:

3.2.1 Sampling Method

The sampling design in this study is based on ranked set sampling method. Ranked set sampling is a two-phase sampling process that reduces the number of samples required, using a more expensive measurement [Mcintyre, G.A., 1952]. Ranked set sampling involves initial ranking of n samples of size n , followed by observing the first order statistic from the first samples, the second order statistic from the second samples, and so

on until the n^{th} order statistic from the n^{th} sample yields [Pongpullponsak A. and Sontisamran P., 2010].

Sample size

From the ranked set sampling method, it can be applied to this study as shown in the following:

- Random sample by simple random sampling method which the sample size is about 9,571 samples (at 95% confidence).
 - Allocate 9,571 samples into 9 sets, each set has 9 samples
 - Rank the sample into 9 ranks; the lower northern (L-N), the upper northern (U-N), the lower northeastern (L-NE), the upper northeastern (U-NE), the western (W), the central (C), the eastern (E), the lower southern (L-S), and the upper-southern (U-S)
 - Choose the northern sample from the first set, the north-eastern from the second set, and so on until the southern sample from the last set
 - Repeat step 1 to step 4 856 times, so we will get the 856 data from 9,571 random samples

So, the number of sample must be more than 856 samples to get enough samples for representative of population. The diagram of ranked set sampling method used in this study is shown in Table 3.1.

3.2.2 Questionnaire design

This study uses questionnaires as a tool to assess the fraction of residue removed from the field, the fraction of residue subjected to open burned, and combustion efficiency. Questionnaire in this study is developed from questionnaire of 'Monitoring and Assessment of Biomass Open Burning in Agricultural Areas/Lands in Thailand' project [Garivait, S. et al., 2005].

Questionnaires used in this study (see Appendix A) composed of 5 parts: background information of interviewee, paddy field characteristic, planting characteristic, rice straw and stubble management, and rice field residues burning characteristic. The information for each part is:

- 1) Background information of interviewee

The objective of this section is to collect the information of farmer. The questions in this section related to name, contact number, and address of interviewee.

Table 3.1 Ranked set sampling used in this study

Cycle	Rank								
	L-N	U-N	L-NE	U-NE	W	C	E	L-S	U-S
1	●	○	○	○	○	○	○	○	○
	○	●	○	○	○	○	○	○	○
	○	○	●	○	○	○	○	○	○
	○	○	○	●	○	○	○	○	○
	○	○	○	○	●	○	○	○	○
	○	○	○	○	○	●	○	○	○
	○	○	○	○	○	○	●	○	○
	○	○	○	○	○	○	○	○	●
	○	○	○	○	○	○	○	○	○
2	●	○	○	○	○	○	○	○	○
	○	●	○	○	○	○	○	○	○
	○	○	●	○	○	○	○	○	○
	○	○	○	●	○	○	○	○	○
	○	○	○	○	●	○	○	○	○
	○	○	○	○	○	●	○	○	○
	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○
...									
N	●	○	○	○	○	○	○	○	○
	○	●	○	○	○	○	○	○	○
	○	○	●	○	○	○	○	○	○
	○	○	○	●	○	○	○	○	○
	○	○	○	○	●	○	○	○	○
	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○
	○	○	○	○	○	○	○	○	○

○ Simple

● Sample measured

2) Paddy field characteristics

The objective of this section is to study the characteristic of paddy field. The question in this section related to size of paddy field, number of paddy field section, frequency of rice planting, and water resource used for rice planting.

3) Rice planting characteristic

The objective of this section is to study the characteristic of rice planting in each area. The question in this section related to period of planting area preparation, period of planting, period of harvesting, varieties of seed, amount of rice production, planting

method, amount of fertilizer, harvest method, selling price, the changing of rice planting pattern during 5 years ago.

4) Rice straw and stubble management

The objective of this section is to study the management of rice residue that mostly used by farmer in each area which used to investigate the fraction of residue removed from the field and the fraction of residue subjected to burned. The question in this section related to utilization or burning, and the ratio of utilization or burning.

5) Rice field residues burning characteristic

The objective of this section is to study the characteristic of rice residue open burned and characteristic of residue after burned which used to assess the combustion efficiency of rice residue. The question in this section related to frequency of burning, size of burned area, type of fuel burned, burning period, ratio of fuel left after burning, and ratio of burned area and planting area.

3.2.3 Data Collection

This study uses direct interview for data collection. It is the method by which interviewer is able to explain the question in the questionnaire to the interviewee. Data collection will be operated by random sample for each region. 95 samples from pre-test and 877 samples are collected from 22 provinces. The criteria used to select the location (province) of questionnaire survey are the size of paddy field in the province, and the spatial distribution of paddy field burning in the province. The size of paddy field obtained from the report of Office of Agricultural Economic (OAE). The spatial distribution of paddy field burning is interpreted from fire hot spot (FHS) detected by Moderate-resolution imaging spectroradiometer (MODIS) sensor aboard the Terra and Aqua satellites. FHS detected by satellite in the paddy field area indicates the area which has a high possibility to open burning. FHS data, $10 \times 10 \text{ km}^2$ grid, and land use map are overlaid together.

From the interpretation found the location of site survey that high of paddy field area and also high density of paddy field burning included 3 provinces in the lower northern region: Nakornsawan, Petchchabun, and Pichsanulok; 2 provinces in the upper northern region: Lampang, and Chiangmai; 3 provinces in the lower northeastern region: Buriram, Nakornratchasima, and Surin; 5 provinces in the upper northeastern region: Khongkai, Konkaen, Mahasarakam, Udonthani, and Nakornpanom; 3 provinces in the western region: Suphanburi, Petchburi, and Ratchaburi; 1 province in the central region: Chainat; 1 province in the eastern region: Chachoengsao; 2 provinces in the lower southern region:

Pattalung and Songkla; and 2 provinces in the upper southern region: Chumporn and Nakornratchasima (See Figure 3.1). The size of sample collected in each region is summarized as shown in Table 3.2.

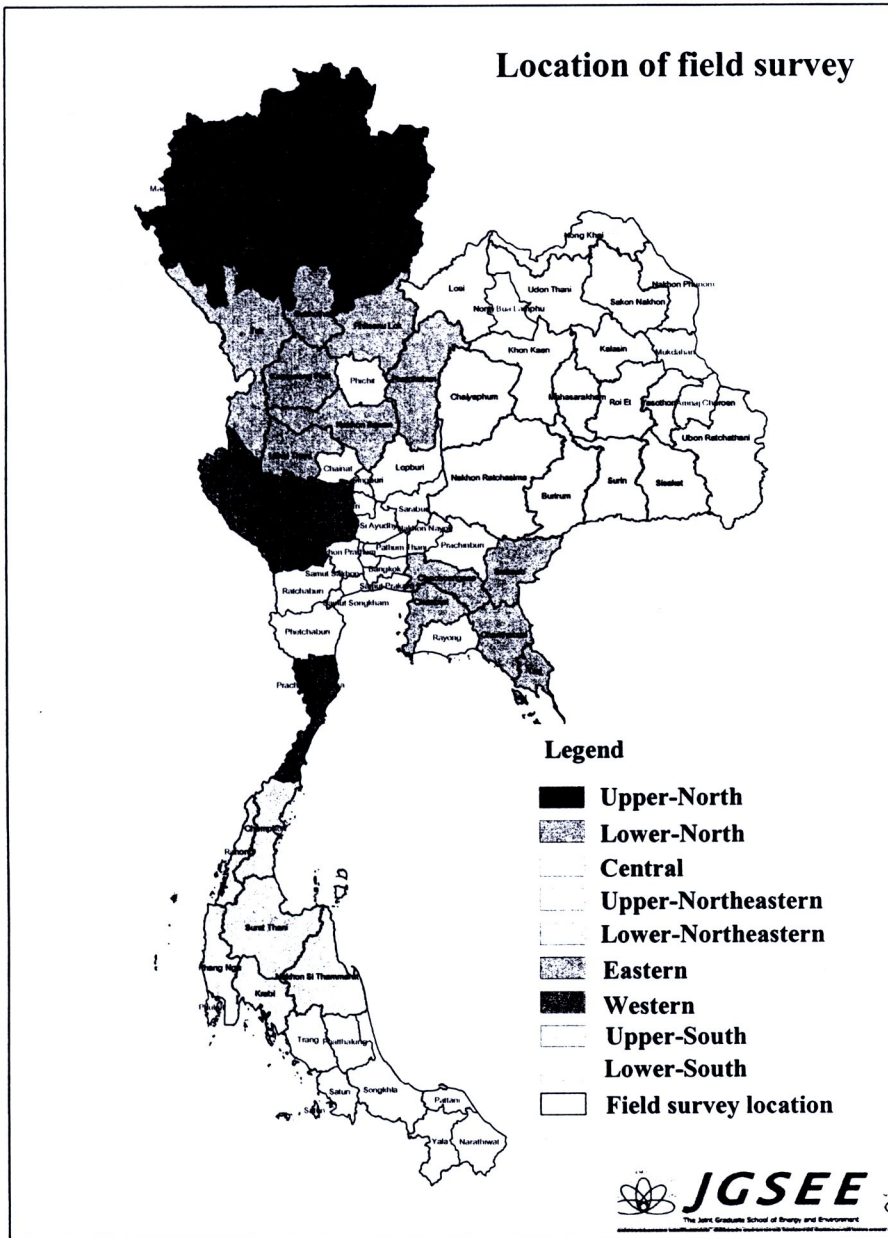


Figure 3.1 Location of questionnaire survey

Table 3.2 The number of samples collected

	Sample number (samples)	
	Pre-test	Test
Lower northern	17	162
Upper northern	3	56
Lower northeastern	25	200
Upper northeastern	20	255
Western	12	68
Central	10	61
Eastern	8	17
Lower southern	0	36
Upper southern	0	20
Total	95	875

3.2.3 Data Analysis

The data from data collection will be distributed to population by using interval estimation method in terms of population mean, population standard error estimation by using Equations 3.1, 3.2, and 3.3.

$$\bar{X}_{rss,j} = \sum_{i=1}^n \frac{X_{(i:n)j}}{n} \quad j = 1, 2, \dots, r \quad \text{--- (Equation 3.1)}$$

$$SD(\bar{X}_{rss,j}) = \sqrt{\sum_{i=1}^n \frac{\sigma_{(i:n)}^2}{n^2}} \quad \text{--- (Equation 3.2)}$$

$$SE(\bar{X}_{rss,j}) = \frac{SD(\bar{X}_{rss,j})}{\sqrt{n}} \quad \text{--- (Equation 3.3)}$$

Where:

- \bar{X}_{RSS} = the population mean from ranked set sampling method
- $SE(\bar{X}_{RSS})$ = the standard error of mean from ranked set sampling method
- $SD(\bar{X}_{RSS})$ = the standard deviation from ranked set sampling method
- n = the size of sample
- j = the number of repeat cycles
- μ = the sample mean

3.3 Results and Discussion

3.3.1 Summary of result from questionnaire survey

The summary of data from questionnaire survey is shown as follows:

3.3.1.1 Paddy field characteristics

The questionnaire part 2 relates to the characteristics of paddy fields. Based on the information (as shown in Tables B.1 and B.2, Appendix B) from 972 farmers found the average field size is about 1.9-4.5 ha (SD 1.00-2.19 ha) with the average plantation frequency 1.0-2.1 round/year (SD 0.00-0.60 round/year).

3.3.1.2 Cultivation characteristics

The questionnaire part 3 relates to the characteristics of cultivation. Based on the information in this section (as shown in Tables B.3 to B.16, Appendix B) from 972 farmers is summarized as follows:

In case of major rice: the average period of pre-cultivation is about 1.0-2.8 months (SD 0.00-0.55 months) which is mainly during May to July. The average period of rice cultivation is about 3.6-3.8 months (SD 0.21-0.25 months) from July to August, the average period of harvesting is about 1.0-3.3 days (SD 0.00-2.40 days) which exclude drying time; from October to December. For characteristics of rice cultivation, the percentage of field by plantation method is in the range of 14% to 100% and 0% to 86% for broadcast method and transplant method respectively. The percentage of field by harvest method is in the range of 0% to 88% and 12%-100% for human and machine respectively. The top three of rice variety that mainly plant is Kao-Dok-Mali 105, RD 6, and Suphanburi 1. The average of chemical fertilization is about 150-313 kg/ha (SD 28.8-36.9 kg/ha).

In case of minor rice: the average period of pre-cultivation is about 0.3-1.8 months (SD 0.32-0.33 months) mainly during January to March. The average period of rice cultivation is about 3.5-4.0 months (SD 0.00-0.39 months) which mainly start in January to February. The average period of harvesting is about 1.0-3.2 days (SD 0.00-2.70 days) which exclude drying time, mainly during April to May. For characteristics of rice cultivation, the percentage of field by plantation method is in the range of 62% to 100% and 0% to 38% for broadcast method and transplant method respectively. The percentage of field by harvest method is in the range of 0% to 34% and 67%-100% for human and machines respectively. The rice variety is in the group of non-photo sensitivity as Chainat

1, Suphanburi, and Pathumthani. The average of chemical fertilization is about 231-369 kg/ha (SD 33.1-105.6 kg/ha).

3.3.1.3 Rice residue management characteristics

The questionnaire part 4 relates to the characteristics of rice residue management. Based on the information in this section (as shown in Tables B.17 to B.19, Appendix B) from 972 farmers is summarized as follows:

In case of major residue, major-stubble and major-straw are mainly used. The share of the field that uses major-stubble and major-straw is in the range of 31%-90% and 25%-93% respectively.

In case of minor residue, minor-stubble is mainly burned. The share of the field that burned minor-stubble is in the range of 11%-78%. Minor-straw is also used and burned which the share of the field about 34%-88%.

Taken into consideration of utilization, all of stubble is mainly left and incorporated into the field whereas straw is mainly sold or given away.

3.3.1.4 Rice residue burning characteristic

The questionnaire part 5 relates to the characteristic of burning of rice residue. Based on the information in this section (as shown in Tables B.20 to 22, Appendix B) from 972 farmers is summarized as follows:

The reason for burning is to clear fields. 64%-100% of the burned area attends to burned stubble and straw and 0%-36% of the burned area attends to burn only stubble. Take into consideration on the characteristic of the residue after burning which represents the combustion efficiency of straw found the major-straw is mainly burned about 51%-75% whereas the minor-straw is burned about 51%-75% and 76%-99% as well. For the characteristics of the area after burning which represents the combustion efficiency of stubble found the major field and minor field is mainly burned about 51%-75%.

3.3.2 Rice field residue management

Regarding the data from the questionnaire on characteristics of rice stubble and straw management (part 4) found some of residue is used outside the field. The unused residue is either burned or left in the field. The information of the utilization and burning of rice stubble and straw is summarized as follows:

3.3.2.1 Percentage of residue used outside the field (U)

Part 4 of questionnaire data provides details on rice straw and stubble management (the summary of this part is shown in the previous section). The percentage of utilized rice field residue was estimated from 3 types of information: (1) information of paddy field area by type of residue (major-straw, major-stubble, minor-straw, and minor-stubble), residue management (use only, use and burn, and burn only), and region (see Table B.17, Appendix B) and (2) information of percentage of utilization of straw by fraction of straw and region (see Table B.18, Appendix B), and (3) information of percentage of utilization of stubble by fraction of stubble and region (see Table B.19, Appendix B).

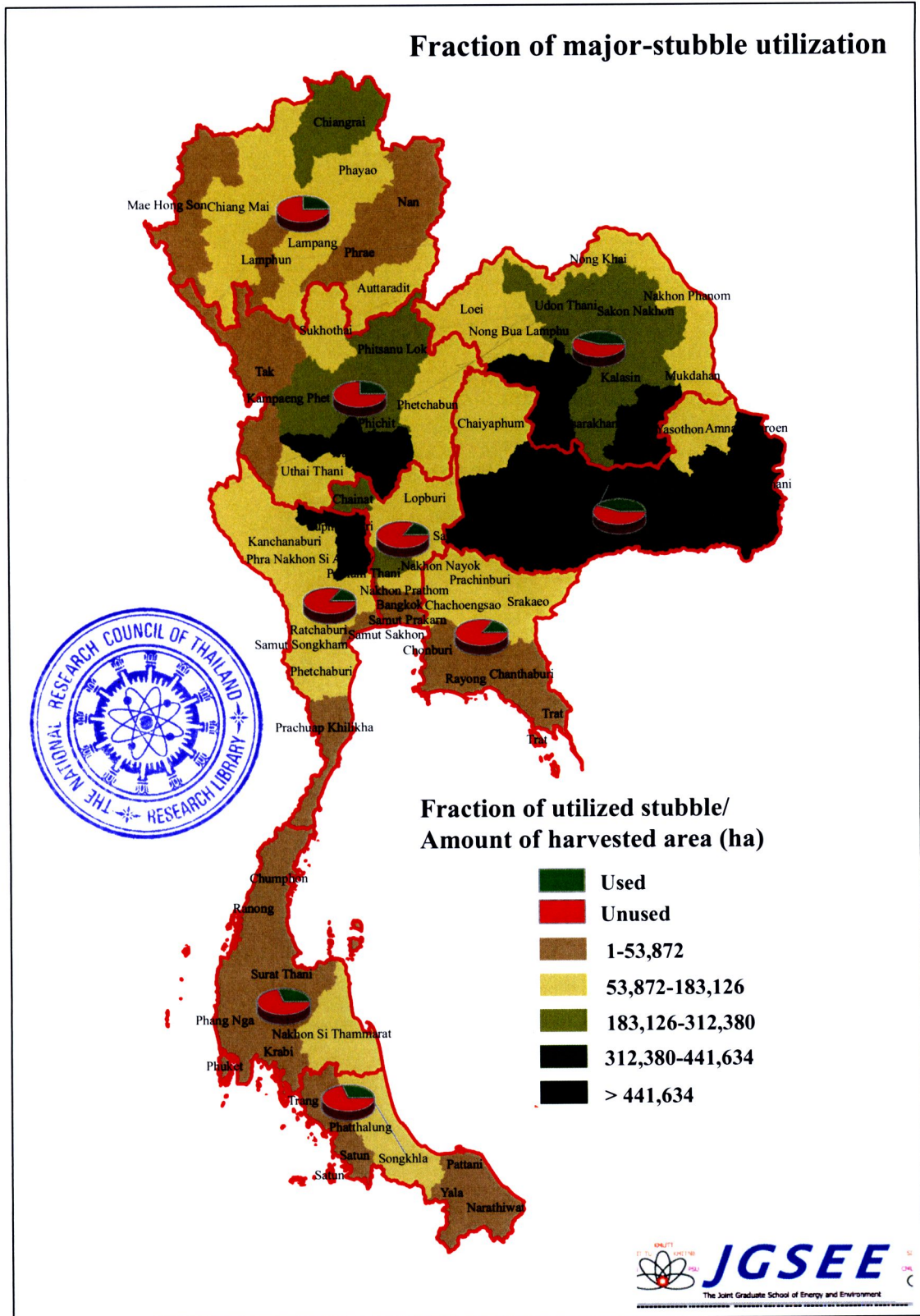
The percentage of utilized major-stubble, major-straw, minor-stubble, and minor-straw in the upper northern and the lower northern regions was about $25\% \pm 0.4\%$, $60\% \pm 1.0\%$, $29\% \pm 0.3\%$, and $36\% \pm 0.4\%$ respectively; in the central, the western, and the eastern regions was about $16\% \pm 0.4\%$, $57\% \pm 1.4\%$, $11\% \pm 0.2\%$, and $26\% \pm 0.5\%$ respectively; in the upper northeastern and the lower northeastern regions was about $44\% \pm 1.2\%$, $93\% \pm 2.6\%$, $34\% \pm 0.6\%$, and $57\% \pm 1.1\%$ respectively; in the upper southern, and the lower southern regions was about $30\% \pm 0.6\%$, $78\% \pm 1.5\%$, $32\% \pm 0.4\%$, and $41\% \pm 0.6\%$ respectively. The percentage of utilized rice field residue by type of residue as major-stubble, major-straw, minor-stubble, and minor-straw and region is shown in Figures 3.2 a – 3.2 d.

From this result found $50\% \pm 6.0\%$ of major-residue and $30\% \pm 3.1\%$ of minor-residue was used outside the field. The main residue used outside the field is major-residue. This result is in the range of the previous study that reported the fraction of residue uses as grow mushroom, animal feed, household fuel, sold, and so on is in the range of 5%-90% [Devendra, C., 1996; DEDE, 2003; Asia Biobusiness Pte, Ltd, 2006; Gadde, B., 2009].

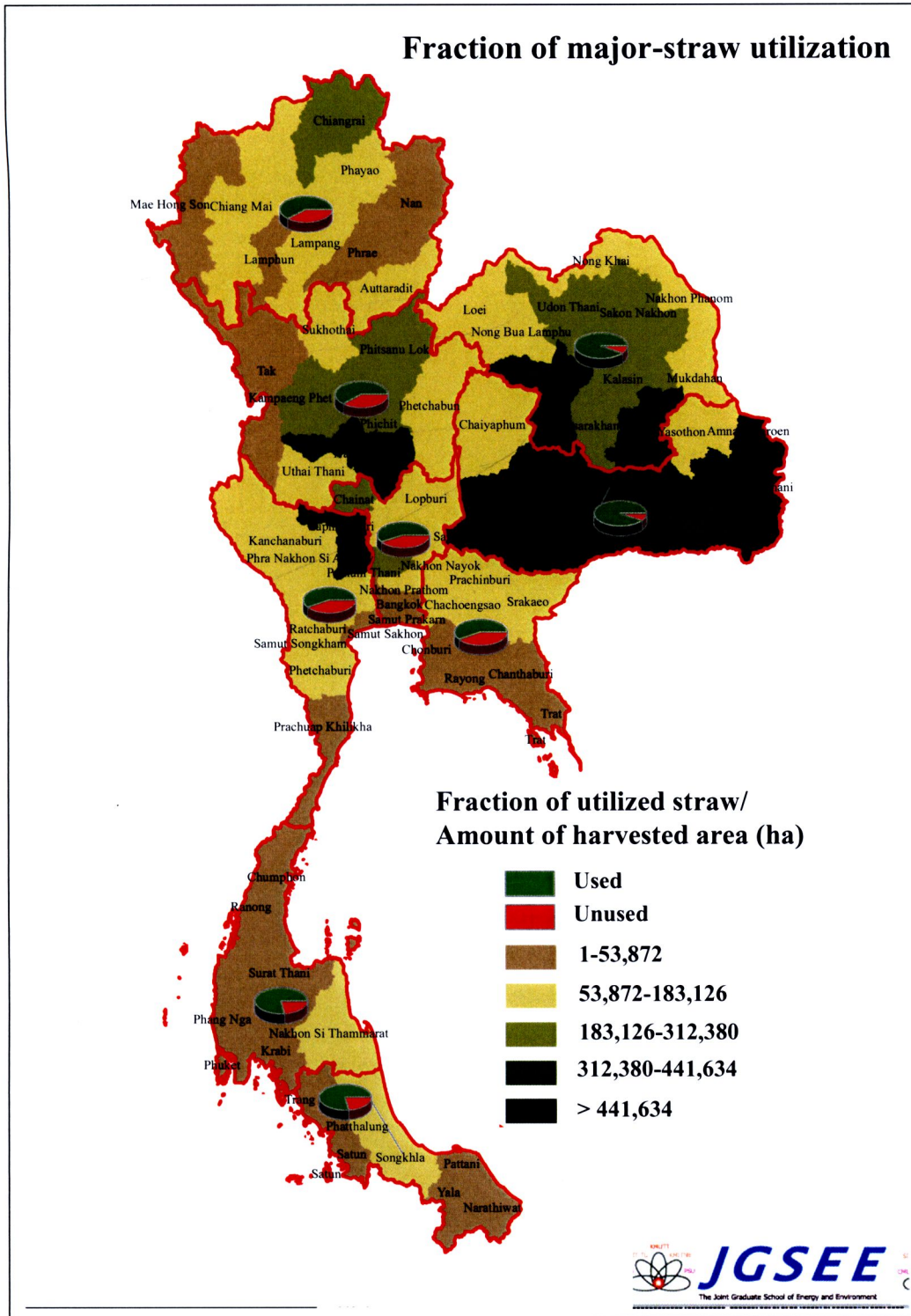
Taken into consideration on the utilization of residue by type of residue (stubble/straw) found no matter major-residue or minor-residue, rice straw is used more than rice stubble. About $56\% \pm 5.0\%$ of overall straw and $28\% \pm 2.5\%$ of overall stubble is used for some purpose as animal feed, mushroom plantation, sale, fuel, and so on.

Consideration of the utilization of residue by type of residue and region found the amount of utilized stubble and straw varies on region. For major-stubble, the amount of utilized major stubble varies on 16%-44% (SD 0.4%-1.2%); the northeastern (lower and upper) is the region that the most use of major-stubble, followed by the southern (lower

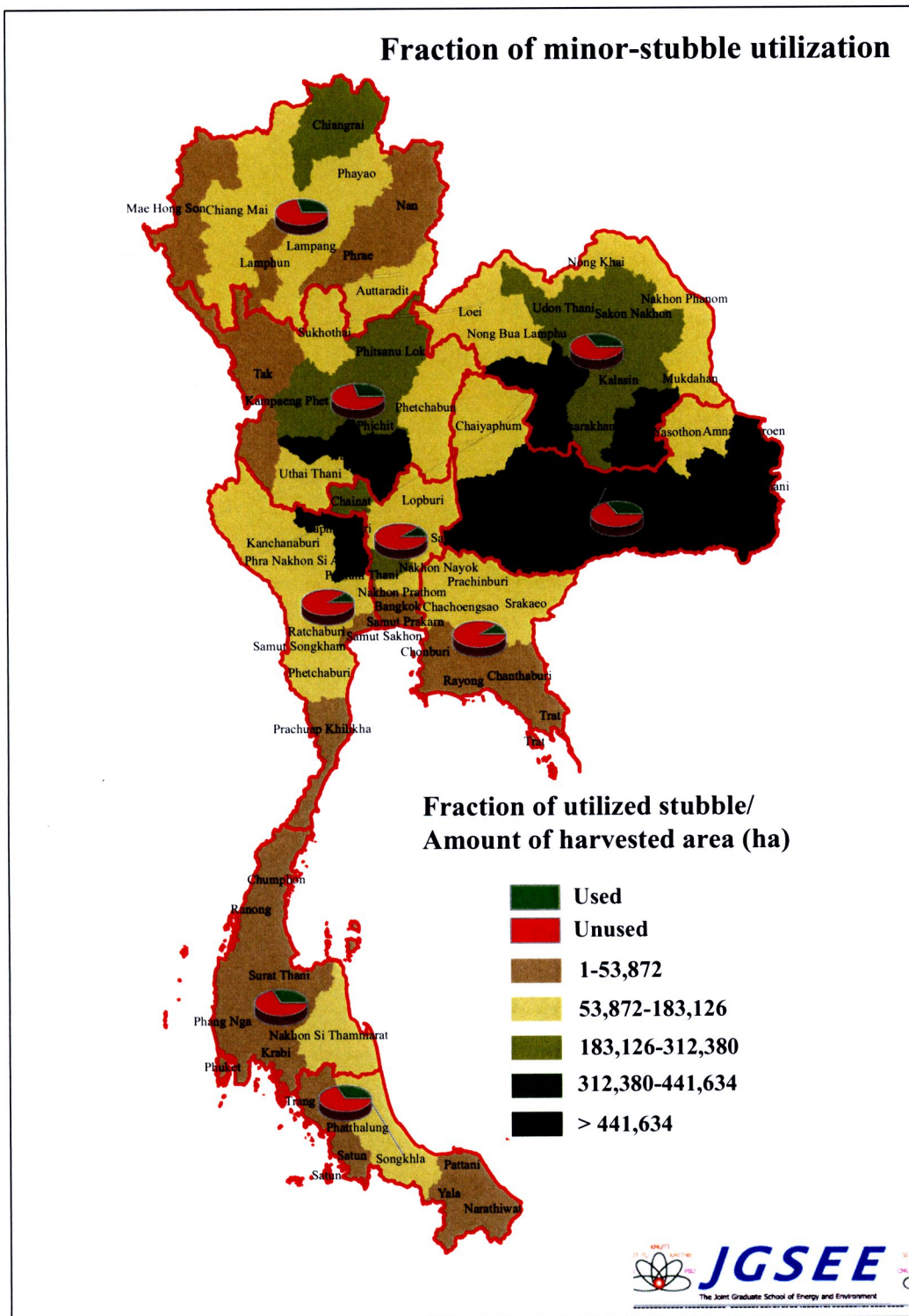
and upper), the northern (lower and upper), and the last is the central. For minor-stubble, the amount of utilized minor stubble varies on 11%-34% (SD 0.2%-0.6%); the northeastern



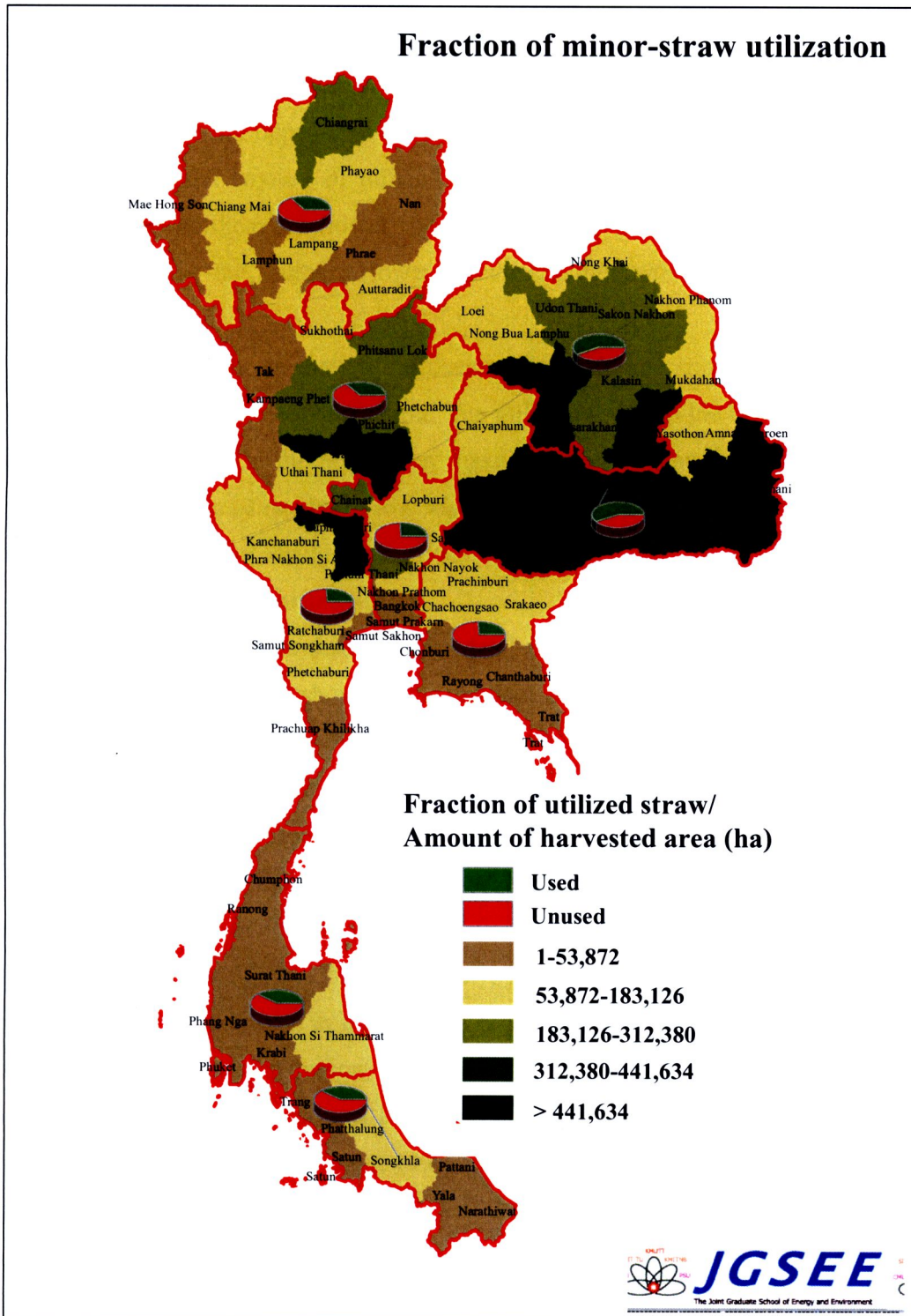
3.2 (a) Fraction of utilized major stubble



3.2 (b) Fraction of utilized major straw



3.2 (c) Fraction of utilized minor stubble



3.2 (d) Fraction of utilized minor straw

Figure 3.2 Fraction of residue utilization by type of residue

(lower and upper) is the region uses most of the major-stubble, followed by the southern (lower and upper), the northern (lower and upper), and the last is the central. For major-straw, the amount of utilized major straw varies on 57%-93% (SD 1.4%-2.6%); the northeastern (lower and upper) is the region that the most use of major-straws, followed by the southern (lower and upper), the northern (lower and upper), and the last is the central. For minor-straw, the amount of utilized minor straw is in the range of 26%-57% (SD 0.5%-1.1%); the northeastern (lower and upper) is the region that the most use of major-straws, followed by the southern (lower and upper), the northern (lower and upper), and the last is the central.

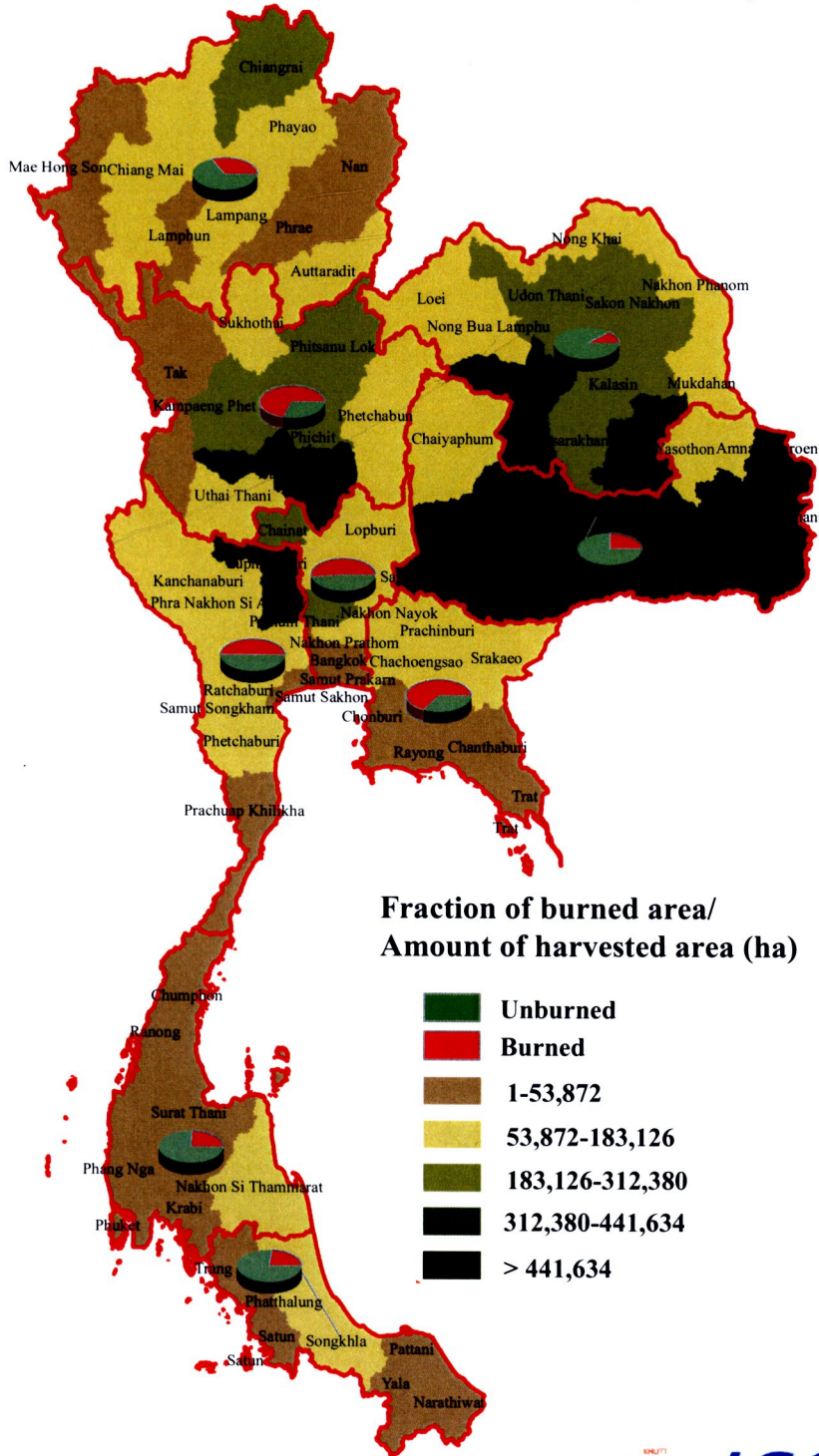
These results indicate that the utilization of stubble and straw have similar patterns that vary on the frequency of plantation. The utilization of residue has inversely with the plantation frequency. In the area where has the high frequency of plantation as in the central, the utilization of residue is low whereas the low plantation frequency as the northeastern, it has the high of residue utilization.

3.3.2.2 Amount of burned area

Part 4 of questionnaire data provides details on rice straw and stubble management. (The summary of this part is shown in the previous section). The percentage of burned area obtained from the information of paddy field area by type of residue (major-straw, major-stubble, minor-straw, and minor-stubble), residue management (use only, use and burn, and burn only), and region (see Table B.17, Appendix B).

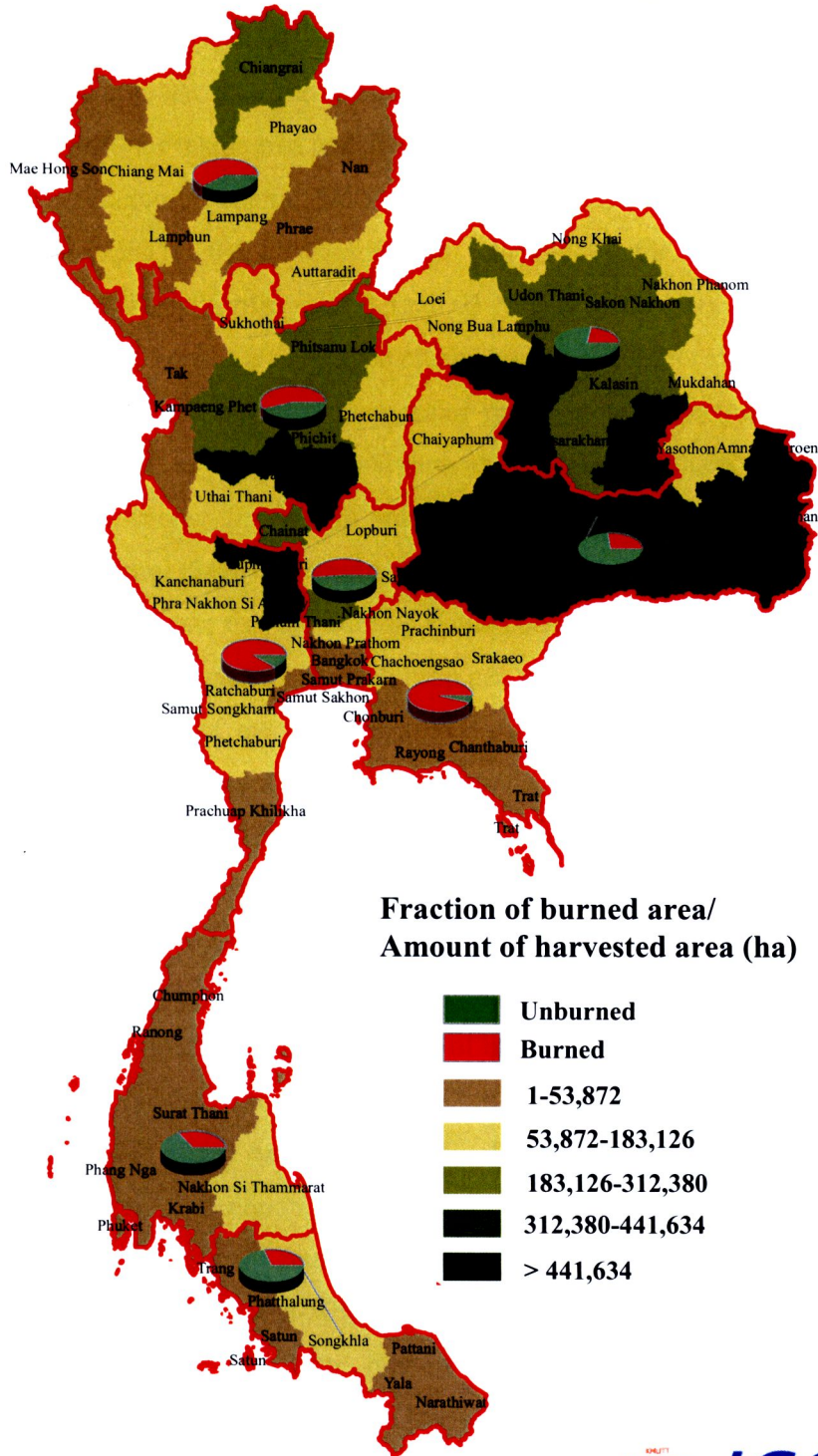
The percentage of major field burned and minor field burned in the upper northern region was about $34\% \pm 4.1\%$ and $60\% \pm 2.8\%$ respectively; in the lower northern region was about $69\% \pm 6.3\%$ and $55\% \pm 3.3\%$ respectively; in the central region was about $52\% \pm 6.8\%$ and $52\% \pm 2.9\%$ respectively; in the western region was about $50\% \pm 4.2\%$ and $89\% \pm 3.5\%$ respectively; in the eastern region was about $63\% \pm 3.7\%$ and $95\% \pm 6.5\%$ respectively; in the lower northeastern region was about $25\% \pm 2.2\%$ and $27\% \pm 1.2\%$ respectively; in the upper northeastern region was about $10\% \pm 1.5\%$ and $22\% \pm 1.7\%$ respectively; in the lower southern region was about $23\% \pm 2.4\%$ and $30\% \pm 7.3\%$ respectively; and in the upper southern region was about $24\% \pm 3.6\%$ and $35\% \pm 5.1\%$ respectively. The percentage of burned area in the major field and minor field is shown in Figures 3.3a and 3.3 b respectively.

Fraction of burning of major rice area



3.3 (a) Fraction of major area burned

Fraction of burning of minor rice area



3.3 (b) Fraction of minor area burned

Figure 3.3 Fraction of area burned

From this result found during 2007-2008, the overall amount of burned area was about 3.9 ± 0.35 Mha or about 36% of overall paddy field, included 2.6 ± 0.29 Mha of major field (36% of overall major field) and 1.3 ± 0.07 Mha of minor field (65% of overall minor field). The result is lower than the report of PCD that reported the percentage of burned area was about 50% for major area and 75% for minor area [PCD, 2006].

Take into account the spatial distribution of burned area found the area which has the maximum of burning is the lower-northern, followed by the central and the western (0.97 ± 0.10 Mha, 0.79 ± 0.06 Mha, and 0.51 ± 0.03 Mha respectively). Consideration on the spatial distribution of burned area by type of rice (major rice/minor rice) found the burning is occurred in the minor rice more than major rice. The average fraction of major area burned varies on 10% to 69% that maximum in the lower-northern (24% of burning of major area). The average fraction of minor area burned varies on 27% to 95% that maximum in the central (34% of burning of minor area).

These results indicate that the burning in the paddy field also relates to the frequency of plantation. The region where has multi-crop per year as the central and lower-northern, it has a high possibility of the occurrence of burning which associated to the result of previous study [Suramaythangkoor, T., and Gheewala, S.H., 2008].

3.3.2.3 Combustion efficiency

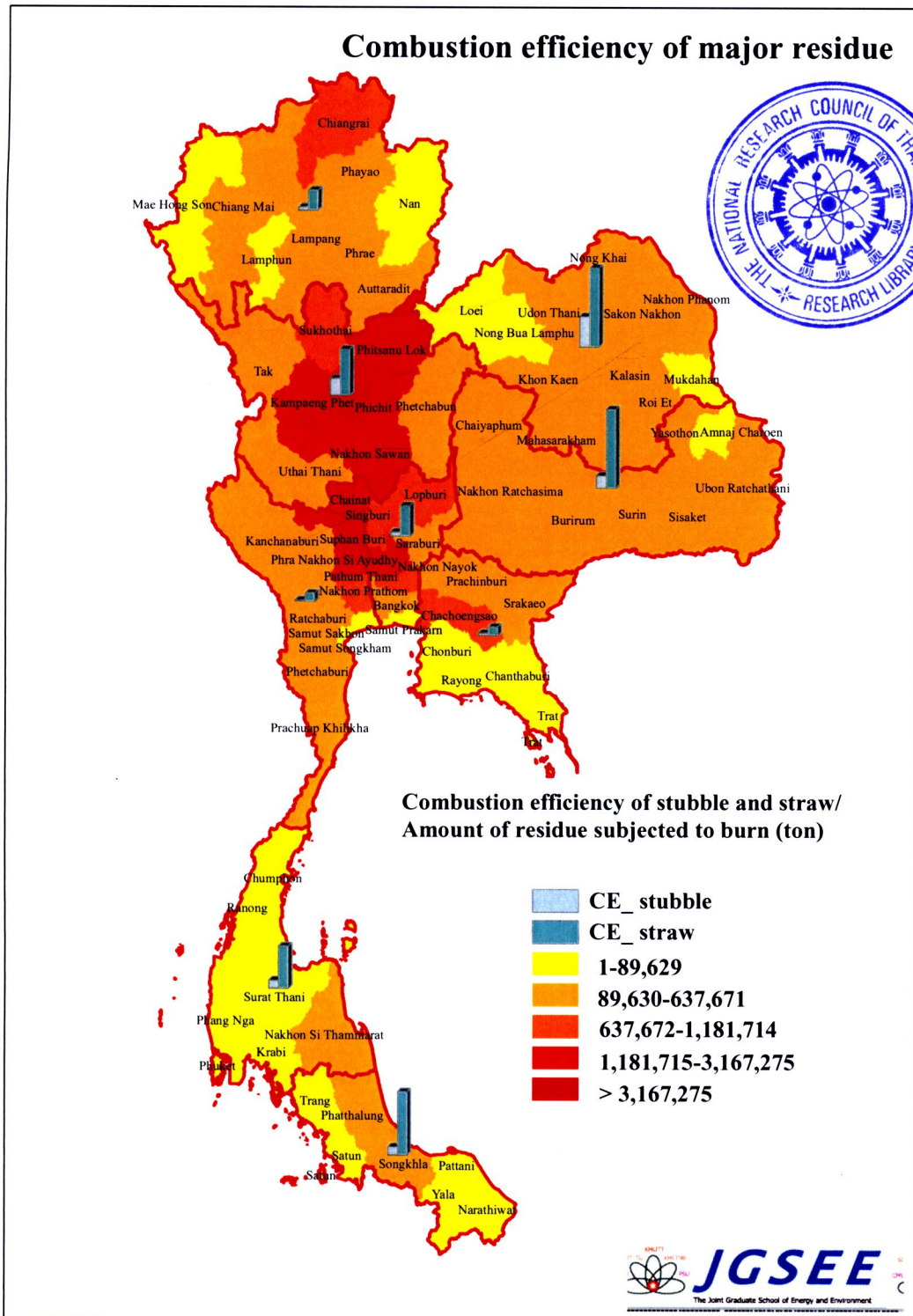
The combustion efficiency is the fraction of residue consumed by fire. Part 5 of questionnaire data provides detail on rice field residue burning characteristic. (The summary of this part is shown in the previous section). The combustion efficiency obtained from 2 information: (1) information of burned paddy field by fraction of residue burned (100% of residue burned/ 76%-99% of residue burned/ 51%-75% of residue burned/ 26%-50% of residue burned,/ 1%-25% of residue burned), type of residue (major residue/minor residue), and region (see table B.21, Appendix B) (2) information of burned paddy field by fraction of area burned (100% of area burned/ 76%-99% of area burned/ 51%-75% of area burned/ 26%-50% of area burned,/ 1%-25% of area burned) that represented to the burning of stubble, type of residue (major residue/minor residue), and region (see table B.22, Appendix B). The fraction of residue burned equals to the fraction of burning of rice-straw whereas the fraction of burned area assumes to be the fraction of burning of rice-stubble.

The combustion efficiency for major-stubble/major-straw/minor-stubble/minor-straw in the upper northern region was about 0.20 ± 0.02 , 0.54 ± 0.01 , 0.21 ± 0.01 , and 0.68 ± 0.02

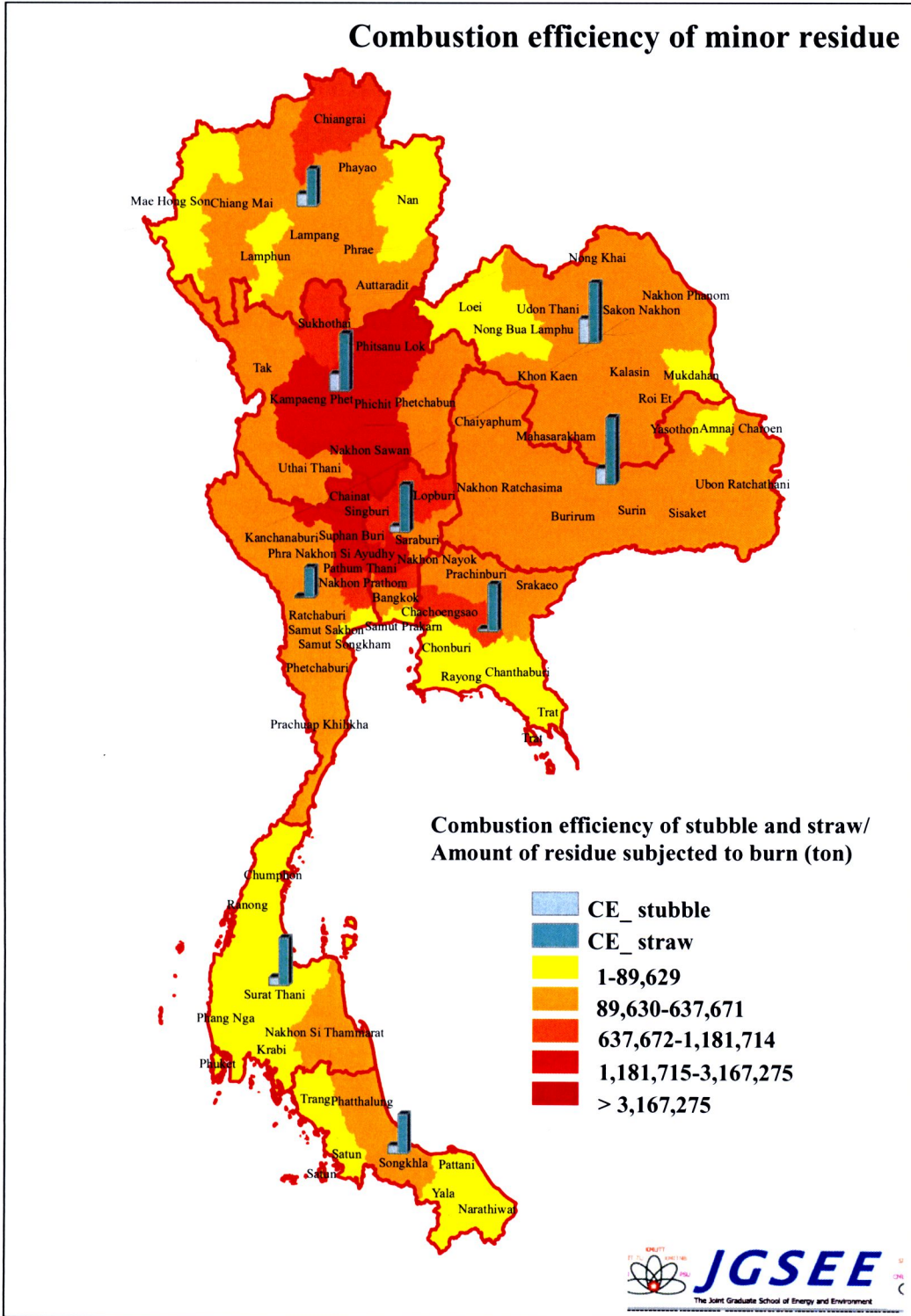
respectively; in the lower northern region was about 0.04 ± 0.02 , 0.24 ± 0.01 , 0.15 ± 0.01 , and 0.44 ± 0.02 respectively; in the central region was about 0.05 ± 0.03 , 0.36 ± 0.02 , 0.07 ± 0.01 , and 0.56 ± 0.02 respectively; in the western region was about 0.02 ± 0.01 , 0.10 ± 0.02 , 0.02 ± 0.01 , and 0.36 ± 0.02 respectively; in the eastern region was about 0.03 ± 0.03 , 0.10 ± 0.02 , 0.04 ± 0.01 , and 0.56 ± 0.02 respectively; in the upper northeastern region was about 0.36 ± 0.02 , 0.93 ± 0.02 , 0.29 ± 0.01 , and 0.71 ± 0.01 respectively; in the lower northeastern region was about 0.15 ± 0.02 , 0.93 ± 0.02 , 0.19 ± 0.01 , and 0.71 ± 0.01 respectively; in the upper southern region was about 0.10 ± 0.01 , 0.50 ± 0.02 , 0.10 ± 0.02 , and 0.56 ± 0.02 respectively; and in the lower southern region was about 0.10 ± 0.01 , 0.75 ± 0.02 , 0.10 ± 0.02 , and 0.46 ± 0.02 respectively. The value of combustion efficiency by type of residue (major-stubble/major-straw/minor-stubble/minor-straw) and region is shown in Figure 3.4.

From this result found the average of combustion efficiency was about 0.45 for major residue and 0.40 for minor residue. It demonstrates major residue was more burned than minor residue. The literature review on the value of combustion efficiency found the value was in the range of 0.25-0.96 [ONEP, 1990; Scholes, R.G., et al., 1996; I. Ortiz de Za'rate, et al., 2005; Garivait, et al., 2005].

Taking into account the combustion efficiency by type of residue found the combustion efficiency of major-stubble is in the range of 0.02-0.36 which the average about 0.18 ± 0.04 . The combustion efficiency of major-straw is in the range of 0.10-0.93 which the average is about 0.72 ± 0.10 . The combustion efficiency of minor-stubble is in the range of 0.02-0.29 which the average about 0.17 ± 0.02 . The combustion efficiency of minor-straw is in the range of 0.44-0.79 which the average is about 0.65 ± 0.03 . It demonstrates no matter major rice or minor rice, straw was burned more than stubble. Straw was consumed by fire more than stubble because of its lower moisture content. Moreover, farmer always start fires with the driest straw, so straw is easier to combust especially the upper part of straw.



3.4 (a) CE of major residue



3.4 (b) CE of minor residue

Figure 3.4 Combustion efficiency of rice residue

Taking into consideration the combustion efficiency by type of residue and region found straw was more burned than stubble for all regions. The region that has the highest of combustion efficiency was the upper-northeastern, followed by lower-northeastern. The northeastern has the highest combustion efficiency because of main of paddy field in the northeastern was in the rain-fed area which was the dry area. It is suitable for burning.

These results indicate that the value of combustion efficiency depends on moisture content of residue and humidity in the area. This is in agreement with 2006 IPCC Guidelines that reported the combustion efficiency is a function of the size and architecture of the fuel load, the moisture content of fuel and the type of fire.

3.4 Conclusions

This part studied the rice residue management by using questionnaire survey. This study interviewed 972 farmers based on ranked set sampling method in 22 provinces including 2 provinces in the upper northern region: Lampang, and Chiangmai; 3 provinces in the lower northern region: Nakornsawan, Petchchabun, and Pichsanulok; 1 province in the central region: Chainat; 3 provinces in the western region: Suphanburi, Petchburi, and Ratchaburi; 1 province in the eastern region: Chachoengsao; 5 provinces in the upper northeastern region: Khnongkai, Konkaen, Mahasarakam, Udonthani, and Nakhonpanom; 3 provinces in the lower northeastern region: Buriram, Nakhonratchasima, and Surin; 2 provinces in the upper southern region: Chumporn and Nakhonratchasima; and 2 provinces in the lower southern region: Pattalung and Songkla. The sampling location was selected from the paddy field area (obtained from annual statistical of Office of Agricultural Economics) and the fraction of burned paddy fields (obtained from the interpretation of fire hot spot (FHS) detected by Moderate-resolution imaging spectroradiometer (MODIS) sensor aboard the Terra and Aqua satellites, $10 \times 10 \text{ km}^2$ grid, and land use map).

The questionnaire used in this study included 5 parts: (1) Background information of the interviewee, (2) Paddy field characteristics, (3) Rice planting characteristics, (4) Rice straw and stubble management, and (5) Rice field residues burning characteristics. Information from Parts 2 and 3 represented the characteristic of paddy field and rice cultivation that will be used as background information for assessment the amount of residue and the emission from rice cultivation. Information from Parts 3 and 4 represented the characteristics of rice residue management and residue burning that will be used to assess the spatial and temporal distribution of residue burning and emission from burning.

Regarding the questionnaire information on characteristics of major paddy field and rice cultivation (questionnaires Parts 2 and 3) found the average period of pre-cultivation is about 1.0-2.8 months (SD 0.00-0.55 months) mainly during May to July. The average period of rice cultivation is about 3.6-3.8 months (SD 0.21-0.25 months) which mainly start in July to August. The average period of harvesting is about 1.0-3.3 days (SD 0.00-2.40 days) which exclude drying time; mainly during October to December. About 14%-100% of major rice field uses broadcast method whereas about 0%-86% of major rice field uses transplant method. About 0%-88% of major rice field uses human harvest whereas about 12%-100% of major rice field uses machine harvest. The top three of rice variety that mainly plant is Kao-Dok-Mali 105, RD 6, and Suphanburi 1. The average of chemical fertilization is about 150-313 kg/ha (SD 28.8-36.9 kg/ha).

Regarding the questionnaire information on characteristics of major paddy fields and rice cultivation (questionnaire Part 2 and Part 3) found the summary of questionnaire survey data that related to minor rice plantation characteristics: the average period of pre-cultivation is about 0.3-1.8 months (SD 0.32-0.33 months) which mainly during January to March. The average period of rice cultivation is about 3.5-4.0 months (SD 0.00-0.39 months) which mainly start in January to February. The average period of harvesting is about 1.0-3.2 days (SD 0.00-2.70 days) which exclude drying time; mainly during April to May. About 62%-100% of minor rice field uses broadcast method whereas about 0%-38% of minor rice field uses transplant method. About 0%-34% of minor rice field uses human harvest whereas about 67%-100% of minor rice field uses machine harvest. The rice variety is in the group of non-photo sensitivity as Chainat 1, Suphanburi, and Pathumthani. The average of chemical fertilization is about 231-369 kg/ha (SD 33.1-105.6 kg/ha).

Based on questionnaire survey data on rice residue management (questionnaire part 4) found the average of rice residue that used outside the field is about 40% that classified by type of rice and residue as 27% of major-stubble, 70% of major-straw, 25% of minor-stubble, and 38% minor-straw. The fraction of utilization varies on region which depends on frequency of plantation. 60% of rice residue is unused residue that left in the field.

Questionnaire survey data on the percentage of burned area (questionnaire part 5) found 36% of paddy field is burned that classified by type of rice as 36% of major area and 65% of minor area. The percentage of burned area varies on region which also depends on frequency of plantation. The unused residue left in the burned area is the residue subjected to open burning.

The combustion efficiency is a measure of the proportion of the residue that is actually combusted. From questionnaire survey data on combustion efficiency information found the average combustion efficiency was about 0.18 for major-stubble, 0.72 for major-straw, 0.17 for minor-stubble, and 0.65 for minor-straw. The combustion efficiency variation by region depends on moisture content of residue and humidity in the area.