CHAPTER 8
CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This study attempts to validate the optimum utilization of unused rice field residues to reduce emissions from agricultural open burning. Emission from rice residue burned in the field is a problem. The principal to solve this problem is to manage the residue that subjected to burned in the field. The residue subjected to burn equals to the unused of residue left in the field. There are 2 management methods proposed in this study; agricultural management and energy management.

This study starts from the estimation of generated rice residue by applying relationship between weight and height of rice botanical. Then using these results with questionnaire data for assessment of the amount of residue subject to burned and the amount of actual residue burned in the field. The amount of residue that is combusted in the field multiplies with emission factor to quantify the amount of GHG emissions (CO_2, CH_4, and N_2O) and pollutant (CO, NO_x, $PM_{2.5}$, PM_{10}, and black carbon) from burning of rice residue (based on 2006 IPCC Guidelines method). The result from this study demonstrates the residue burning situation.

Then, 3 residue management scenarios are proposed. GHG emissions in term of CO_{2eq} from each scenario is compared with base line GHG emissions for validation of optimize utilization of unused residue which has amount of emission reduction as an indicator.

This study found the generated of rice residue 117.7 Mt of residue included 59.4 Mt of stubble and 58.3 Mt of straw. 26% of overall residue or about 30.8±7.47 Mt is subjected to burn in the field included 16.8±4.07 Mt of stubble and 14.0±3.38 Mt of straw. 15% of overall residue or about 11.3±2.19 Mt is burned in the field included 2.4±0.49 Mt of stubble and 8.9±1.70 Mt of straw. Burning of 11.3±2.19 Mt contributes GHG as CO_2 13.35±2.595 Mt, CH_4 0.003±0.0006 Mt and N_2O 0.0008±0.0001 Mt and pollutant as CO 1.5±0.29 Mt, NO_x 0.035±0.0007 Mt, and $PM_{2.5}$ 0.31±0.060 Mt. A ton of burned residue emits about 1.26 tonCO_{2eq}.

The utilization of unused residue (residue subjected to burn) for agricultural purposes as incorporation into the soil affects to emission from rice cultivation. In the burned area, the GHG emission from rice cultivation is about 6.46 MtCO_{2eq} or about 1.65 tCO_{2eq}/ha. When increasing a ton of residue incorporated into the soil, the emission from rice cultivation will increase between 0.14 and 1.19 ton of CO_{2eq} under condition 120 days of rice cultivation and 3.125 tons/ha of compost.

The utilization of unused residue (residue subjected to burn) for energy production found 1 MW of electricity in thermal combustion system would require about 9,010 tons of unused straw per year that contributed 0.03 tCO_{2eq} (exclude neutral CO_2) and 0.884 $kgCO_{2eq}$ is avoided from 1 kWh coal power production.

In base line conditions, burning of unused rice residue in the field, then incorporate before cultivation, and coal power production, this case contributes 0.9 $MtCO_{2eq}$ of non-CO_2 and 44.1 Mt of CO_2. In Scenario 1, unused straw and stubble for agricultural purpose, this case contributes 15.0 $MtCO_{2eq}$ of non-CO_2 and 44.1 Mt of CO_2. In Scenario 2, unused straw for power production and unused stubble for agricultural purpose, this case contributes 6.5 $MtCO_{2eq}$ of non-CO_2 and 0.2 Mt of CO_2. In Scenario 3, unused straw in the high power and provincial capacity is used for energy purpose and the left is used for agricultural purpose, this case contributes 13.3 $MtCO_{2eq}$ of non-CO_2 and 1.1 Mt of CO_2.

Based on the comparison of CO_2 emissions and non-CO_2 emissions between base case and each scenario found the emission reduction in the group of CO_2 is higher than non-CO_2. The largest of the net amount of GHG emission reduction is in the case of rice residue for energy utilization (Scenario 2) which more than 90% of CO_2 reduction in base line (-44.7 Mt CO_2) and 12% of non-CO_2 reduction in base line (-0.8 Mt CO_{2eq}), followed by using for energy and agricultural utilization (scenario 3) which about 43.0 Mt CO_{2eq} reduction in base line and 6.8 Mt CO_{2eq} increased of non-CO_2 in base line. Using for agricultural is the smallest of net of emission reduction which about 2% of CO_2 reduction in base line (-0.9 Mt CO_2) and 4 % increased of non-CO_2 in base line (+7.7 Mt CO_{2eq}).

This study demonstrates the principal of emission mitigation from burning of unused residue is to utilize the unused residue instead of burning. Using rice residue for agricultural purpose as incorporated into soil before rice-cultivation has strongly affected to the non-CO_2 GHG emissions. Using rice residue for energy purpose as power production has affected to the CO_2 GHG emissions but in case of rice residue power production, the CO_2 is neglect. So, non-CO_2 GHG emissions are more consideration. The power production contributes non-CO_2 lower than incorporation, so using rice residue for power production is more suitable for open burning emission mitigation. In terms of environmental friendly, the optimal solution is using for energy purpose. In terms of environment and implementation, the optimal solution is using for agricultural and energy purpose due to the feasible consideration.

8.2 Recommendations

8.2.1 Determination of generated rice field residues

This study determines the generated rice field residues from applying the relationship between weight and height of rice stalk. This relationship is developed based on the principal of empirical model. Factors considered in this are planting method (transplanted/broadcast) and seasonality (major rice/minor rice). The amount of rice residue still depends on other factors as amount of fertilization, water regime, soil type, and so on. So, in the future study should consider on these factors to develop more accuracy of the model.

8.2.2 Rice field residue management

This study studies the management of rice field residue using questionnaire survey. The sampling data bases on rank set sampling method. The questionnaire survey data is interpolated for population representation. So, the accuracy of the result strongly depends on the data sampling.

8.2.3 Emissions from rice field residue burning

Questionnaire in this study is designed for study on the behavior of rice residue open burning. It is not used for study on the violence of rice residue open burning. The factor that represented the violence of the burning is the combustion efficiency (CE) which relates to burning emission. To study on combustion efficiency, it need to consider on the other relate factors as climate (temperature, rainfall, humidity, and so on), topography (dry, wet). So the future study on the emission from rice residue open burning, it should consider on these factors.

8.2.4 Emissions from incorporation of rice residue into soil

The amount of emissions from rice cultivation varies on the amount and type of organic amendment incorporated into soil before cultivation. Organic amendment included manure and rice residue. For rice residue, only straw should be consider as the input of organic amendment due to stubble is considered in the starting point of the emission factor.

8.2.5 Emissions from rice residue for energy production

The limitation of this research is about the analysis of demand for energy production. The demand focuses only the potential of unused residue in terms of quantity but not considering technology of straw power plant. To get more accuracy of the potential of rice residue, technology of straw power plant should be considered.

Besides that, to use rice residue for heat or power production, the factors that should be considered are:

- Plant location: heat needs to be produced at the point of heat use, while electricity does not need to be produced at the using point.
- Efficiency: the conversion of biomass to heat is very efficient (up to 90% efficiency) while electricity production is a very inefficient process (20-30%)
- Cost of fuel conversion: cost of heat production is low, while electricity conversion is expensive as the fuel must be converted initially to a gas or to steam before electricity can be generated. This results in power-generating equipment being more capital intensive than heat boilers.
- Product market: heat is a relatively low value product while electricity is relatively high value

8.2.6 Comparison of utilization of unused rice residue

Regarding the comparison of utilization of unused rice residue in energy purpose, this study focuses on the emission mitigation of rice straw power production from coal power production because coal is a main fuel that used for power production in Thailand. In terms of qualification of rice straw (Lower Heating Value; LHV 12.3 MJ/kg), it has the same magnitude of another biomass as husk (LHV 13.5 MJ/kg), leave and top sugarcane (LHV 15.5 MJ/kg), palm shell (LHV 16.9 MJ/kg). So, for future study, the mitigation of rice straw power production from biomass power production is another choice that should be studied.

Furthermore, to develop utilization of unused rice residue scenario, each scenario should be under the same magnitude of the outcome. That will reduce the bias of each scenario.