Greenhouse Gas and Aerosol Emissions from Rice Field and Forest in the Mekong River Basin Sub-Region

Sirintornthep Towprayoon, Sebastien Bonnet, Savitri Garivait and Amnat Chidthaisong

Abstract— *GHG Emission in term of methane and nitrous oxide were estimated using IPCC method with specific emission factor derived from the experimental site in Thailand. The estimation covered rain fed and irrigation rice fields both first and second cultivation in a year and the typical forest types in Thailand and Cambodia. GIS emission map of two land use were established for Mekong River Basin Sub-region using the information from each country. Identification of high emission and sensitive area are at the northeast region of Thailand and around TonleSap area in Cambodia. Carbon monoxide and particulate matter from rice field residue burning and forest fire were also estimated using method developed from IPCC. Data from remote sensing was used to compare the result of GIS map established from the studies. Hot spot of forest fire and biomass burning in Mekong River Basin Sub-region were identified. Both forest fires and paddy field burning activities are observed to peak during the first and last few months of the year from January to April and October to December. This seasonality pattern corresponds to the dry season, period during which there is a lack of rainfall and vegetation fires are therefore detected to take place. Considering biomass burning and biogenic GHG emission, forests in GMS are sources of CO and TPM from biomass burning as well as less significant amount of N_2O from forest soil but are the sink of methane form forest soil. Rice fields with the high contribution for methane emission are likely to emphasize in terms of CO and TPM for local emission problems, while emission from forest should be concerned for the regional or trans-boundary problems.*

Keywords— **GHG emission, biomass burning, Mekong river basin, soil forest, rice field.**

1. INTRODUCTION

South East Asia covers an area of 410 million hectares with forest and agricultural land representing respectively about 77% and 20% of the total area. The agricultural land use in South East Asia has expanded only slightly from 16.8% of total land area in 1975 to 19.6% in 1992, but for the period of 1990-1995, the Asia Pacific forests observed a reduction by 17 million hectares, with the fastest rate in the Mekong region (1.6% per year) and in South East Asia (1.3% per year). Deforestation via burning and intensive agricultural activities results in the increase of GHG and aerosol emissions in the region, which are of main concern for their impacts on the regional air quality and global climate change. To ensure the sustainable development of the region, GHG and aerosols emission inventories need to be established to provide scientific information relevant for the formulation of appropriate control and mitigation strategies. In this study, we generated GIS maps of vegetation land use and corresponding emissions for the Mekong River Basin Sub-region (GMS), the calculation methodologies and data required to perform those emissions calculations were identified.

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2. CLASSIFICATION OF VEGETATION LAND USE IN GMS

To classify the vegetation land use of the GMS, we developed a Geographic Information System (GIS), incorporating a database of digital maps of the 4 countries included in the paper, i.e. Cambodia, Lao PDR, Thailand and Vietnam. Geographic data and their associated attributes, such as vegetation types, secondary data collected from literature review, from governmental agencies in charge of land development or land use management, e.g. Land Development Department in the case of Thailand, and from field surveys.

Two types of vegetation land use are considered in this study: forest and paddy fields. Regarding forest, 6 types were identified in Thailand including, mixed deciduous forest, dry evergreen forest, dry dipterocarp forest, moist evergreen forest and hill evergreen forest. These 6 types were selected on the basis of the calculation method established to estimate biogenic emissions from forest, since emission factors to be used are specific to the type of vegetation. Likewise, for biogenic emissions from rice fields, the emission factors are function of the water management system used for rice cultivation, and hence the classification of paddy fields was categorized in two major classes, i.e. rained and irrigated areas.

From the developed general GIS, the 1:250,000 scale map of vegetation land use including only forest and paddy fields was created, in order to serve as the base layer for locating emission areas.

The land use of the 4 countries of the GMS part of this study is classified in 3 major categories and is reported in Table 1. The corresponding GIS map is displayed in

Figure 1. According to this land use classification, it results that Thailand, with 170,157 km^2, has the largest forest area, followed by Lao PDR, Cambodia and Vietnam. However, with regards to the ratio of forest to total land, Cambodia and Lao PDR, , are largely ahead in the region with about 60% of the country covered with this forest. Concerning paddy fields, Thailand and Vietnam possess the highest numbers. This reflects the position of these two countries as major world producers of rice.

Table 1: Land surface of forest and paddy fields (km^2)

Type	Thailand	Cambodia	Lao PDR	Vietnam
Forest	170,157 (33%)	108,990 (61%)	142,602 (60%)	58,613 (18%)
Paddy fields	105,754 (21%)	17,024 (9%)	2,556 (1%)	48,611 (15%)
Others	237,450 (46%)	55,021 (30%)	91,642 (39%)	223,809 (67%)
Total	514,361	181,035	236,800	331,033

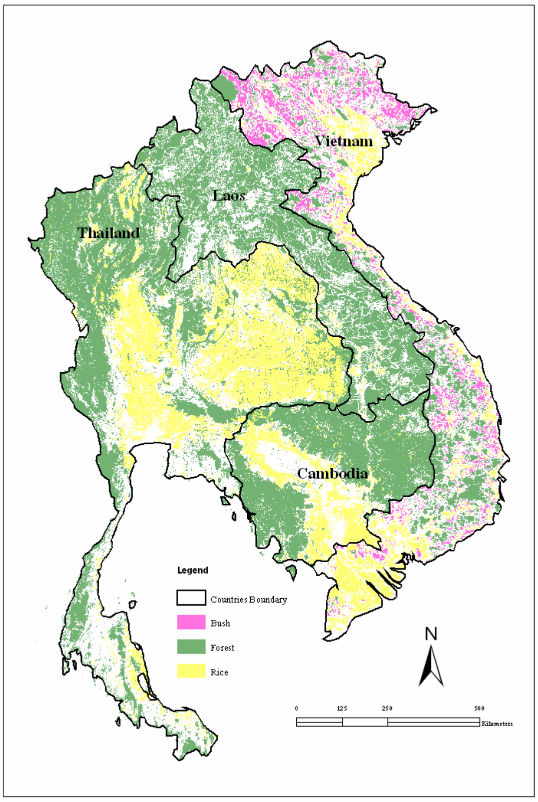

Fig. 1 Land use of GMS

3. ESTIMATE EMISSION

In this study, we estimate amount of greenhouse gases in term of methane and nitrous oxide from two major sources, Forest and rice field. The soil forests are differentiating by forest types and rice fields are differentiate by water management regimes. While aerosol emission, we estimate CO and TPM (total particulate matter) from biomass burns in the forest and agricultural residue (rice straw) burning in the rice field. Emission of these studied GHG and aerosol were expressed in GIS map to show the area of emission for four countries in the Great Mekong Sub-basin namely: Thailand, Laos, Cambodia and Vietnam.

Emissions from biomass burning activities [1]

a) Estimation of amount of biomass burned:

In order to estimate the amount of biomass burned per year as a result of vegetation fires the following general equation is used:

$$M = A \times B \times \alpha \qquad (1)$$

M is the amount of biomass burned per year, (kg/year), A is the area of land cleared (burned) per year (m^2 per year), B is the above ground biomass density (kg/ m^2), and α is the Fraction of above ground biomass burned.

In the case of crop residues burning, the amount of biomass burned is determined using a modified version of the expression given in the IPCC revised guidelines (1996)[2] and also used in works of Hao and Liu (1994) [3] or Streets *et al.*, (2003)[4]. It is as follows:

$$M = P \times D \times B \times F \times \alpha \qquad (2)$$

M is the total mass of crop residue burned in field (kg), P is the crop production (kg), D is the crop specific residue to product ratio, B is the dry matter fraction (or biomass load if P is expressed in unit of surface instead of unit of mass), F is the percentage of dry matter residues burned in field, and α is the burning efficiency

Table 2: Data for estimation of amount of tropical forest and crop residues burned in Asia [2] [3] [4] [5], [6] [7]

Tropical Forest	Biomass load range (kg/m^2)		Burning efficiency	
	10[a]		0.2[b]	
Crops	Residue-to-crop ratio	Dry matter fraction	Dry matter burned in field**	Dry matter burned in field***
Rice	1.76[c]	0.85[d,e,f]	25%[d,e]	17%[d,e]

[a]IPCC (1996); [b]Levine (2000); [c]Koopmans and Koppejan (1997) [d]Hao and Liu (1994); [e]Streets et al., (2003); [f]OEPP, Thailand (1990)

b) Estimation of emissions from biomass burning:

The amount of atmospheric emissions generated annually by biomass burning can be estimated by the product of the amount of dry biomass burned (*Equation 1* or *2*) and the emission factor of a specific pollutant, as follows:

$$E_x = M \times EF_x \qquad (3)$$

E is the emission of the compound x (g/year), M is the mass of dry matter burned (kg dm/year), and EF the emission factor of the compound x (g/kg dm burned).

A comprehensive study from Andrea and Merlet (2001) [1] provides emission factor for various types of biomass burning including tropical forest fires and crop residues burning. These are reported in Table 4.

Table 3: emissions factors [1]. [6]

	Tropical Forest	Crop residues
Compounds	Emission Factors (g/kg)[a]	
CO_2	1580 ± 90	1515 ± 177
CO	104 ± 20	92 ± 84
CH_4	6.8 ± 2.0	2.7
N_2O	0.20	0.07
NOx	1.6 ± 0.7	2.5 ± 1.0
TPM*	20[b]	10[b]

[a]Andrea and Merlet (2001); [b]Levine (2000)

Emissions from biogenic activities

Biogenic emissions from forest can be estimated using the following equation:

$$E = A \times EF \qquad (4)$$

E is the emission of the compound x (mg/year), A is the land area of the forest vegetation (m^2), and EF is emission factors (mg m^{-2} d^{-1})

In order to perform these biogenic emissions calculations the type of forest considered is to be identified as the emissions factors to be applied are vegetation (soil) specific. Emission factors are reported in Table 4.

Table 4: Emissions factors for major types of forest found in the GMS [8]

	Emission Factors	
Types of forest	CH_4	N_2O
Mixed deciduous forest	-0.8	0.3
Dry evergreen forest	-1.5	0.4
Dry dipterocarp forest	-0.8	0.3
Moist evergreen forest	-1.4	0.1
Hill evergreen forest	-2.4	0.3

Vanitchang and Chidthaisong (unpublished data)

Biogenic emissions from paddy fields can be estimated using the following equation:

$$CH4 = Area \ x \ EFw \ x \ t \qquad (5)$$

EFw is the emission factor (kg CH_4 ha^{-1} day^{-1}), t is the cultivation period of rice (day), and A is the harvested area of rice (ha)

The emissions factor indicated in Equation 2 accounts for the differences in water regime during the rice cultivation period. Values are reported in Table 2.

Table 5: Emission factor of water management system for rice fields [9]

Water management	Emission Factor (mg CH_4 m^{-2} d^{-1})	
	CH_4	N_2O
Irrigated (Single aeration)	97.2	0.29
Rain fed	45.7	0.29

** Towprayoon et al 2005 and personal communication*

*** t = average 120 day*

4. GREENHOUSE GASES AND AEROSOL EMISSION FROM FOREST

Greenhouse gases emission in term of CH4 and N_2O was estimated from forest soil using 6 types of forest as representative of GMS forest type. However there are limitation of data accessibility from Laos and Vietnam therefore the estimate focused only for Thailand and Cambodia. Emission factors derived from the experiment in Thailand which showed the negative emission of methane. Total methane emission sink of the two countries was -173.22 ton as seen in Table 5. Mixed deciduous was the major contribution of negative methane emission in both Thailand and Cambodia. Emission of nitrous oxide from soil forest, although the global warming potential was 310, was relatively small.

Aerosol in terms of CO and TSP from biomass burning activity in GMS was estimated. The biomass burning activities observed by ANDES for the 4 countries included in this paper are reported and converted burning area from the fire counts using the resolution of the satellite sensor, which was quite coarse in this case since it was of 2.7 km x 2.7 km. Consequently, each detected fire count was assumed to correspond to a 2.7 km x 2.7 km burned area. It was found that the peak season of forest fires in Thailand, Cambodia, Lao PDR, and Vietnam runs from January to April. Indeed forest fires are significantly detected from October onward, i.e. starting month of the dry season in the region. Result of emission of CO and TMP showed in Table 6. In general fires occurring in dipterocarp and mixed deciduous forest, are generally surface or ground fires, consuming only biomass accumulated on the ground surface or litter. These underline the important influence of local conditions or specificity on the emissions, especially those related to area of land and type of biomass burned. It is therefore of most importance to continue setting up field experiments and surveys to determine and monitor these parameters in the GMS, so as to be able to improve the mission inventory and its assessment. Highest emission of CO and TPM were from Thailand.

Table 6. Emissions from forest fires and forest soil

	Aerosol Emission		GHG Emission from soil	
	CO (ton/year)	TPM (ton/year)	CH_4 (ton/year)	N_2O (ton/year)
Thailand	*6,123,520.00*	*1,177,600.00*	*-144.2*	*39.6*
Cambodia	*2,860,416.00*	*550,080.00*	*-29.022*	*12.030*
Vietnam	*1,323,920.00*	*254,600.00*	*NE*	*NE*
Lao PDR	*2,116,192.00*	*406,960.00*	*NE*	*NE*
Total	*12,424,048.00*	*2,389,240.00*	*-173.222*	*51.6*

Table 7. Emissions from rice field

	Aerosol Emission from burning		Greenhouse Gas Emission from cultivation	
	CO (ton/year)	TPM (ton/year)	CH_4 (ton/year)	N_2O (ton/year)
Thailand	*79,705.85*	*8,663.68*	*1,059,330.17*	*5,630.82*
Cambodia	*7,944.40*	*863.52*	*147,328.60*	*827.13*
Vietnam	*37,303.55*	*4,054.73*	*NE*	*NE*
Lao PDR	*1,205.78*	*13.,06*	*NE*	*NE*
Total	*126,159.58*	*13,581.93*	*1,206,658.77*	*6,457.95*

5. GREENHOUSE GASES AND AEROSOL EMISSION FROM RICE FIELD

Using the emission factors obtained from measurement in Thailand, emission of CH_4 and N_2O from rice field of the whole country was estimated, based on the total area and land use classification. Estimation is only possible in these two countries because the information on land use classification in other countries is not available. Estimates were divided into irrigated and non-irrigated rice. Irrigated rice accounted for about 32% of the total CH_4 emission because rice is usually grown twice a year and emission per unit area for irrigated rice is about twice that of the rain-fed. On the other hand, although rain-fed rice area accounts for about 80% of total growing area, it contributed around 68% of total CH_4 emission (1.1 ×106 tons). However, only about 18% of total N_2O emission was from irrigated rice. Amount of CO and TMP estimate from rice field burning were lower than emission from forest due to the lower amount of residue burn. Major emission from rice field comes from cultivation.

Figure 2 illustrates that methane is contribute largely in the northeast of Thailand and around Tonle Sap of Cambodia. Figure 3 shows distribution of CO and TPM in GMS area.

6. CONCLUSION

Comparing two major emission sources, forest and rice field in GMS, rice fields act as the GHG source in term of methane while forest soil likely to become the sink. Although the forest area is larger than rice field the magnitude of sink and source cannot be comparable. However it is interested to study more on soil respiration where GHG sink can be interpreted as CO2 to increase capacity of sink by tropical forest. It is also noted that the EF of negative methane emission in the paper is in the early step of study. Both forest and rice field are source of nitrous oxide but not in the significant emission. On the contrary to GHG emission, aerosol shows greater contribution from forest which is due to the large burning area as well as control and management system in each country. CO from forest fire is quite large when compare to rice field. Although small amount of CO come from rice field burning but this source is closer to large community. The magnitude of aerosol emission can help confirm that emission from forest is likely to involve in regional problem than rice field which contribute more or less on local problem.

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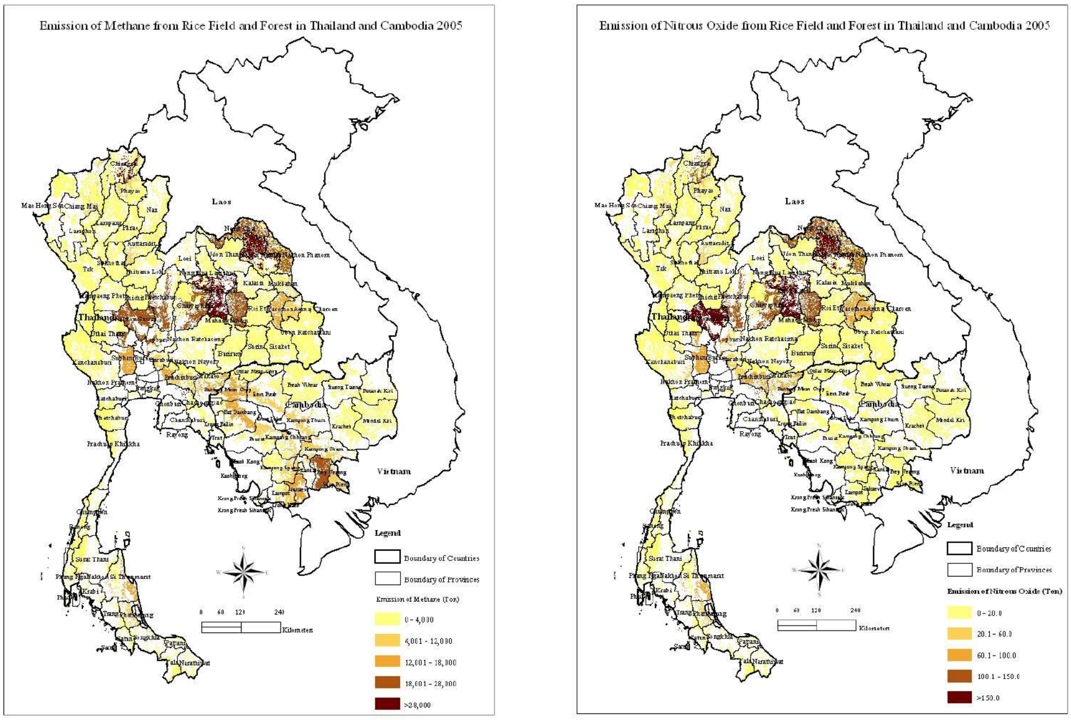

Fig. 2. Total CH_4 and N_2O emission from rice field and forest in Thailand and Cambodia

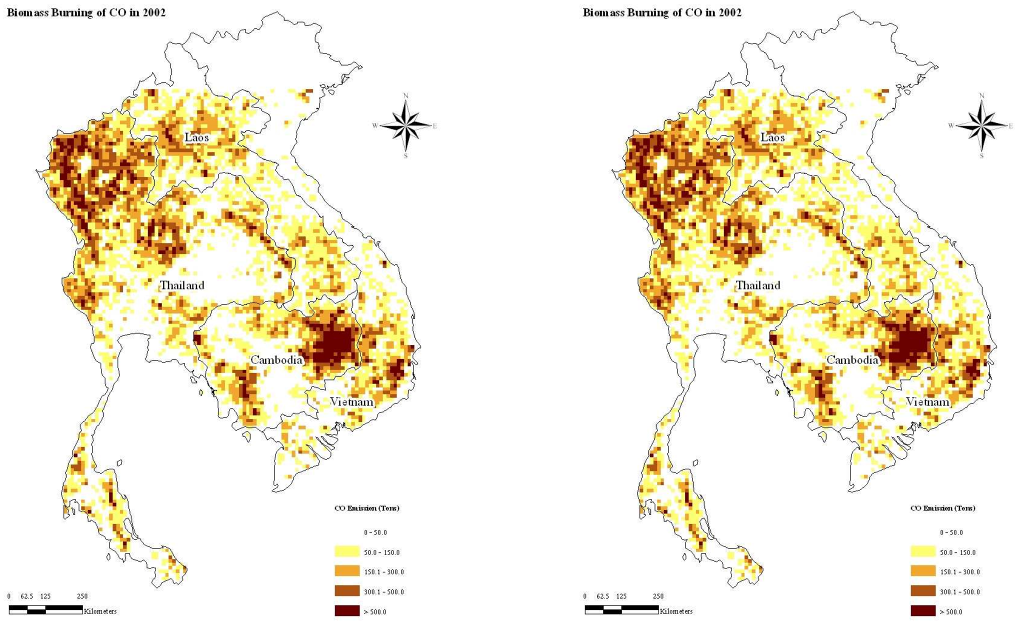

Figure 3. Total Emission of CO and TMP from GMS countries.

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