Estimation of Greenhouse Gases Emission (GHG) From Forest Fire

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ABSTRACT

Tropical forest plays an important role in the process of global carbon cycling. They hold most of terrestrial carbon, which is stored in vegetation and in the organic soil layer. Disturbance regime, including fire, can significantly affect the global net carbon flux and accelerating global environmental changes, trough releasing additional CO2 and Non-CO2 Trace gases such as methane (CH4), Carbon mono oxide (CO), Nitrous Oxide and N2O, Oxides of Nitrogen (NOx), gases to the atmosphere. Thus, estimating GHG loading from forest fire/biomass burning in tropical area is an important part of understanding the contribution of tropical deforestation, especially forest fire to global climate change. Estimation of GHG emission from forest fire should base on at least three important factors: (1) area burned, (2) pre-burn carbon/biomass per type area and (3) burn severity. Estimation of area burned can be conducted by employing Remote sensing and Geographical Information System, while estimating biomass and burn severity should be conducted by experiment in the field. We are trying to investigate techniques to determine area affected by forest using Remote Sensing and Geographical Information System, as well as field experiment/research to estimate biomass, emission ratio and burning efficiency. Finally, the data and information gained will be used to estimate regional GHG emission.

1. INTRODUCTION

1.1. Introduction

Deforestation, permanent land-use cover change from forest to other uses, in tropical countries has been an international concern. Barbier *et al.* (1991) estimated approximately 7 million hectares of tropical forest has been destroyed annually. Various factors have contributed to the deforestation process, such as population growth (Palo, 1994), logging operations (Kummer, 1991), shifting cultivation (Thapa & Weber, 1990), re-settlement (Hurst, 1990), road construction (Hirsch, 1987), international debt (Kahn & McDonald, 1994) and Government policies (Repetto & Gillis, 1988) and In Indonesia, forest fire has been considered as one of the causes of deforestation. The State Ministry of Environment of the Republic Indonesia (1996) stated that deforestation rate came from forest fire was about 100 000 hectares per year. Saharjo (2002) has estimated that the figure officially published is too low, since in one ocassion fire can burn 10 million hectares of forest or bush as occurred in 1997/1998.

Tropical forest plays an important role in the process of global carbon cycling. They hold most of terrestrial carbon, which is stored in vegetation and in the organic soil layer. Disturbance regime, including fire, can significantly affect the global net carbon flux and accelerating global environmental changes, trough releasing additional CO_2 and Non-CO_2 Trace gases such as methane (CH_4), Carbon mono oxide (CO), Nitrous Oxide and N_2O, Oxides of Nitrogen (NOx), gases to the atmosphere. Thus, estimating GHG loading from forest fire/biomass burning in tropical area is an important part of understanding the contribution of tropical deforestation, especially forest fire to global climate change. Such an estimate should base on at least three important factors: (1) area burned, (2) pre-burn carbon per type area and (3) burn severity (Michalek *et al.*, 2000).

Inter-governmental Panel on Climate Change/IPCC (1996) already published guidance to estimate national emission fo GHG from land-use/land cover changes and forestry sector, that includes method to estimate emission of GHG from forest fire (or biomass burning). Based on the guidance, the IPCC have provided default values, such as biomass stock, emission ratio, and burning efficiency. These default values were counted derived from research result in Tropical America regions. Due to wide variation of fire occurrence (or burning practice), biophysical and climatic condition, the IPCC have strongly recommended that users provide their own value.

To estimate National level or regional level of GHG emission from forest fire accurately in Indonesia is difficult due following constraint :

a. there are wide variation of information on area affected by forest fire
b. there is very limited information on biomass stock, emission ratio, and burning efficiency

To overcome the constraints above, we are trying to investigate techniques to determine area affected by forest using remote sensing and Geographical Information System.

1.2. Objectives and the Importance of the Research

The objectives of the research is to develop a technique to estimate forest fire burned area by employing remote sensing and Geographical Information System. The research outcome will contribute to the better understanding of forest fire impact to global climate change.

2. METHODOLOGY

2.1. Research Area

The study area is located in Tanjung Jabung Timur District, eastern part of Jambi Province. The area situated between 0° 45' and 2°'00 latitude south; 101° 30 and 102°30' longitude east (Fig. 1). The area is dominated by peat land, which is susceptible to fire.

2.2. Landsat Processing And Analysis

In this research time series of Landsat images that acquired after and before forest fire are used. Landsat before fire is classified into several classes of land-cover, and then estimation of biomass will be made by combining information from field measurement. Meanwhile, Landsat image after fire will be used for estimating fire affected area.

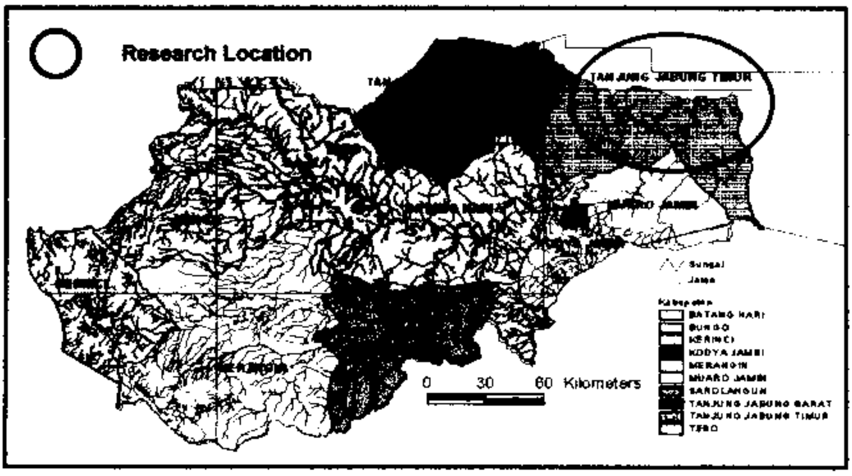

Fig. 1. Research Area

A conventional pixel-based, spectral classification is carried out to identify potential fire areas (**Fig. 2**).The spectral classification is based on a supervised interpretation based on field data. Binairy map of forest fire effected areas substracted from the land cover data and visual interpretation. Final step is overlay between fire scars area, land-cover data before fire and field measurement data, to estimate GHG emission from forest fire.

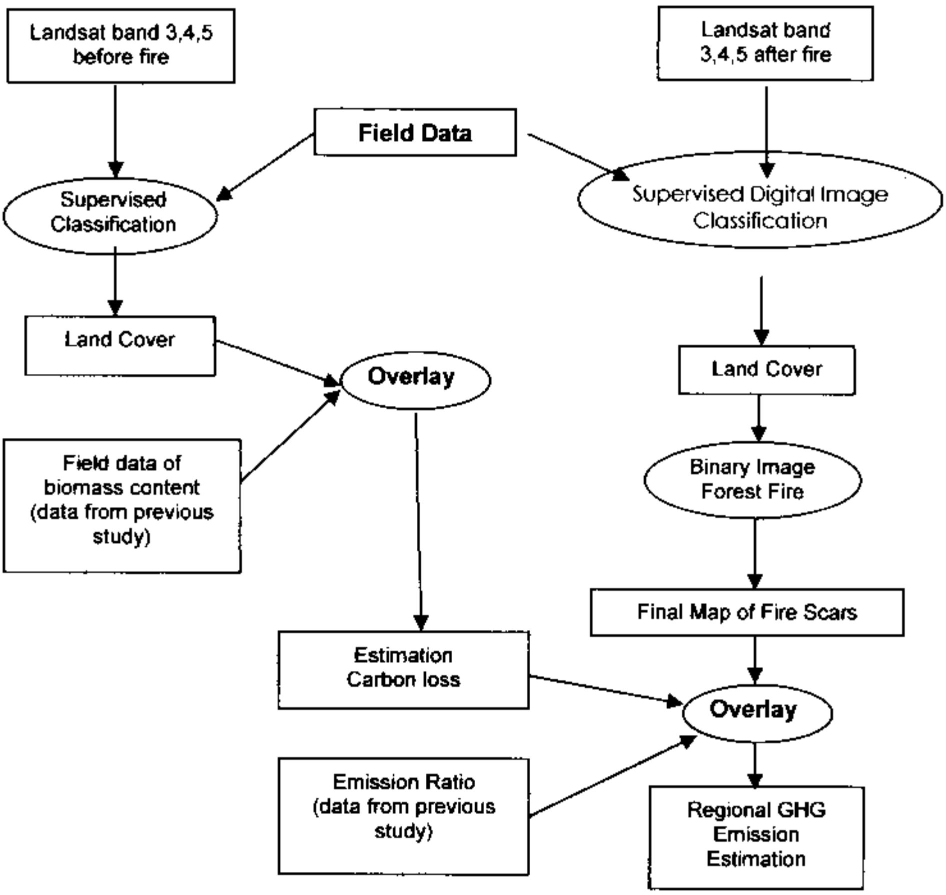

Fig. 2. Flow chart of the research

2.3. Carbon Stock

Data on Carbon stock derived from previous research result, funded by Japan Environmental Agency (Table 4.1) (Prasetyo, *et al.*) It was calculated based on allometric equation, based on Kira & Iwata (1989), especially for trees (forest). Another types of vegetation were estimated based on literature review.

2.4. Emission Estimation of GHG from Biomass Burning

Carbon emission from biomass burning is estimate by using modified equation proposed by Skole, Moore and Chomentowski, (1994) :

$$MC_j = (B_{ij} * 0.50)\ A_{ij}\ b_i \qquad (1)$$

Where MC_j is the amount of C release at location j, B_{ij} is the aboveground biomass for cover type I at j, constant of 0.50 is conversion factor from biomass to C, A_{ij} is the area of cover type i burned at location j and b_i is combustion efficiency for cover type i. b_i is assumed 1 (100%).

Further CO, CH_4, N2O , CH3Cl, CH3Br, and CH3I, release from biomass burning can be added using following equation (Skole, Moore and Chomentowski, 1994).

$$FC_j = MCO_{2j} + (MCO_{2j} * ECO_{ij}) + (MCO_{2j} * ECH_{4ij}) + (MCO_{2j} * EN_2O_{ij}) + (MCO_{2j} * ECH3Cl_{ij}) + (MCO_{2j} * ECH_3Br_{ij}) + (MCO_{2j} * ECH3I_{ij}) \qquad (2)$$

Where MCO_{2j} is the CO_2–C released at location j, ECO_{ij} is the emission ratio of CO2 to CO for cover type I at location j and ECH_{4ij} is the emission ratio of CO_2 to CH_4 for cover type I at location j, EN_2O_{ij} is the emission ratio of CO_2 to N_2O for cover type I at location j, $ECH3Cl_{ij}$ is the emission ratio of CO_2 to CH_4 for cover type I at location j, ECH_3Br_{ij} is the emission ratio of CO_2 to CH_3Br for cover type I at location j $ECH3I_{ij}$ is the emission ratio of CO_2 to CH3I for cover type I at location j.

Emission ratio was derived from previous research funded by Japan Environmental Agency. It was found that emission ratio per CO_2 of secondary forest fire for CO, CH_4, N_2O, CH_3Cl, CH_3Br and CH_3I are 0.265, 0.0093, 0.000061, 0, 0,0000001, and 0, respectively. Meanwhile Gas conversion factor from C to CO2 is 0.50.

3. RESULT AND DISCUSSION

3.1. Research Site Condition

Research site was a forest concession of Logging company, started since 1971 were practicing selective cutting for log production (Fig. 3). The company already terminated and recently part of the area were delivered to an Industrial Forest Plantation company, to plant Acacia trees (*Acacia mangium*). During the site preparation in 1998, a huge forest fire have occurred, destroying most of natural forest remain.

Some part of the research site is also National Park and Nature Reserve. It is under the boundary of Berbak National Park and Pantai Timur Nature Reserve. Berbak

National Park is designed to protect wetland ecosystem, while Pantai Timur nature Reserve for mangrove and its ecosystem protection.

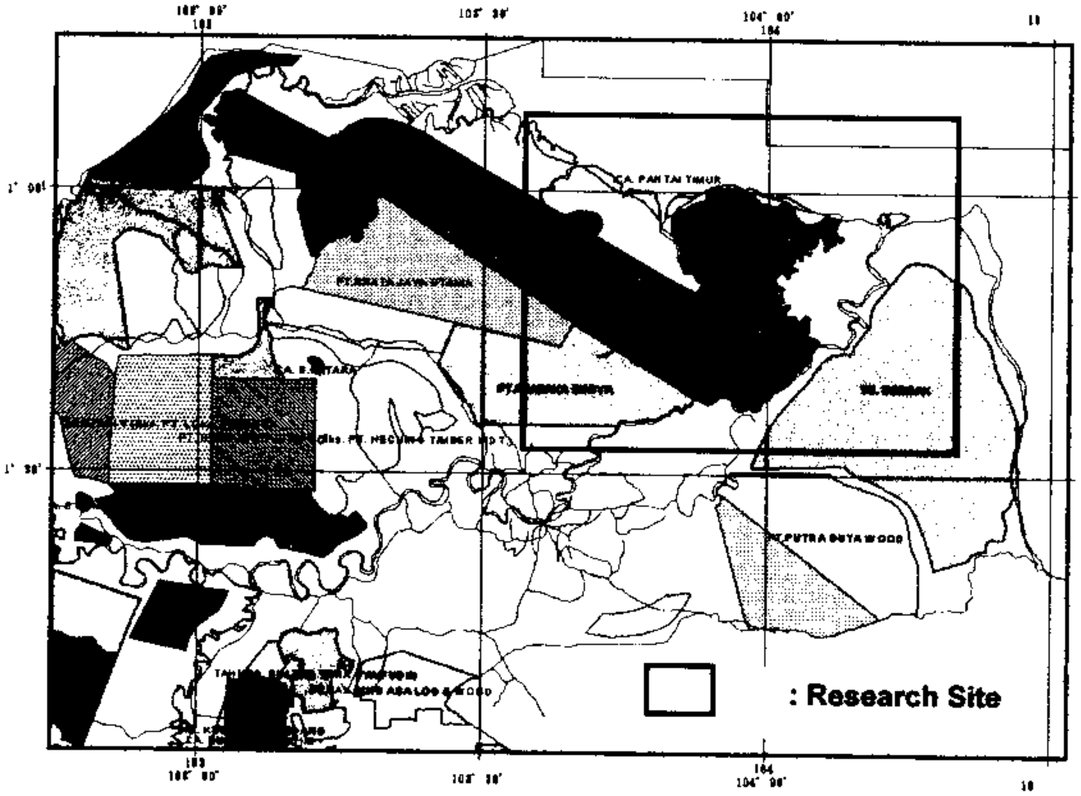

Fig. 3. Research Site

3.2. Land cover changes

Total study area is estimated about 687. 4 thousand hectare, most of them is dominated by forest area. During period of study (1989 – 1998), Natural forest showed significant decrease, meanwhile Rubber jungle have tended to increase During almost ten years, rubber jungle increase almost two times (Table 2). Forest cover decrease of about 91.172 thousand hectare, most of them due to forest fire (74.76 thousand hectare).

Fig. 4 (A) and Fig. 4 (B), showed the spatial distribution of Land-cover/land use of the study area. From the figures, spreading areas of forest fire can be seen clearly. Most of them distributed in forest concession area and only a minor within the National Park.

3.3. Carbon lost and Greenhouse Gases emission due to forest fire

Amount of carbon loss of each land cover/land-use due to forest fire calculated by overlaying binary maps of forest affected areas and land cover in 1989. Binary maps of forest fire affected areas is presented in Figure 4.C, and its statistics result is presented in Table 3. From Table 3, carbon loss from each land-use/land cover can be calculated, as presented in Table 4.

3.4. Emission Estimation of GHG from Biomass Burning

Total carbon loss due to forest fire was estimated about 10 521 038.86 tons. To estimate carbon released directly from forest fire into the atmosphere, some assumptions were made, as follows :

(a) 50% of biomass of forest were removed from the site before forest burn, due to the fact that forest had been exploited before, in which commercial trees were removed from the study site.
(b) Combustion Efficiency is assumed 1 (100%).

Estimation of Greenhouse Gases release into atmosphere from forest fire during 1989 – 1998, is presented in Table 5.

From Table 4.5. it is clearly seen that forest fire have contributed to the global climate changes. Total gas CO_2, CO, CH_4, N2O, CH3Br, and CH_3I emitted to the atmosphere are 5.2 million ton, 1.4 million ton, 48.9 thousand ton, 0.3 thousand ton and 0.53 ton, respectively.

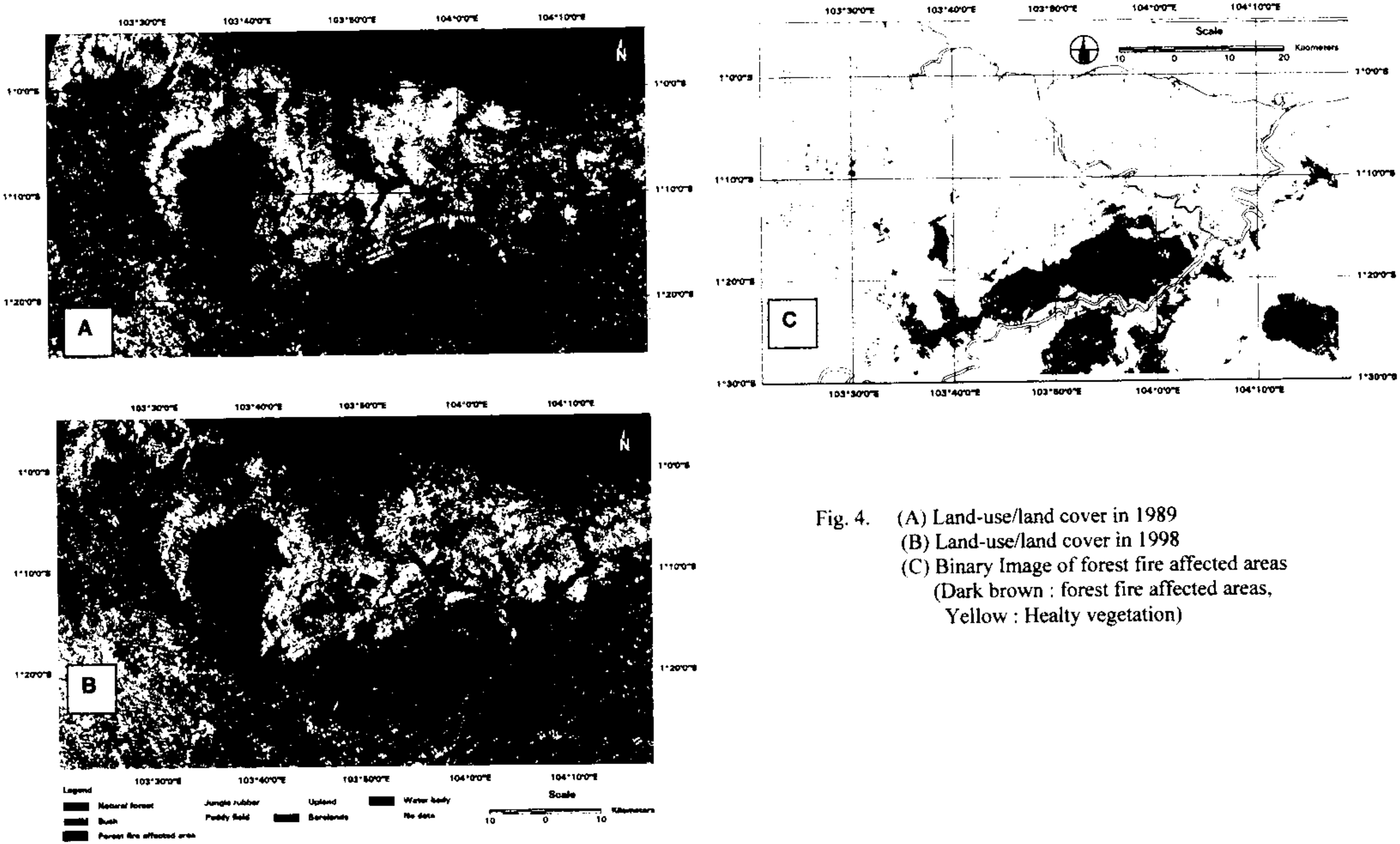

Fig. 4. (A) Land-use/land cover in 1989
(B) Land-use/land cover in 1998
(C) Binary Image of forest fire affected areas
(Dark brown : forest fire affected areas,
Yellow : Healty vegetation)

4. CONCLUSION

The GIS and Remote Sensing technique that we proposed can be incorporated with field data measurement to up-scaling the GHG emission of regional scale.

The application of the technique have been tested to identify forest fire area and to estimate GHG emission of Eastern part of Jambi Province area. Based on the calculation, it is proved that forest fire gave significant impact to global climate changes.

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Table 1. Carbon stock of each land covers.

Land-use/Land cover	Carbon stock per ha(ton C)
Logged forest	155.2
Bush/Shrubs (fallow land)	15
Rubber and sec. vegetation	35.5
Grasslands	6.0
Bare lands	0

Table 2. Land cover changes before and after forest fire

Land-cover	1989	1998	Change	% Change
Natural forest	297339.93	206167.32	-91172.61	-30.66
Bush	87803.37	97517.97	9714.60	11.06
Jungle rubber	27860.40	54377.64	26517.24	95.18
Paddy field	52389.09	34875.00	-17514.09	-33.43
Upland	34069.86	57937.86	23868.00	70.06
Bare lands	62626.23	41880.96	-20745.27	-33.13
Water body	93778.20	88332.75	-5445.45	-5.81
No data	31571.01	31571.01	0.00	0.00
Fire affected areas	0.00	74762.82	74762.82	
Total	687438.09	687423.33		

Table 3. Damage area of each land-use/land cover caused by forest fire.

Land cover	Area (Ha)	%
Natural forest	67286.61	90.00
Bush	3933	5.26
Jungle rubber	359.46	0.48
Paddy field	623.79	0.83
Upland	443.07	0.59
Bare lands	1769.67	2.37
Water body	347.22	0.46
Total	74762.82	100

Table 4. Total carbon loss caused from forest fire

Land-use/ Land cover	Area (Ha)	C (Ton/Ha)	Total C
Natural forest	67286.61	155.2	10442881.87
Bush	3933.00	15	58995.00
Jungle rubber	359.46	35.5	12760.83
Paddy field *	623.79	1.35	3742.74
Upland *	443.07	1.35	2658.42
Bare lands	1769.67	0	0.00
Water body	347.22	0	0.00
Total	74762.82		10521038.86

* estimated equal to Grasslands

Table 5. GHG emission from forest fire

GHG emission (Ton)							
GHG	CO2	CO	CH_4,	N_2O	CH_3Cl	CH_3Br	CH_3I
Emission rasio	0.5	0.265	0.0093	0.000061	0	0.0000001	0
GHG Emission	5260519.43	1394037.65	48922.83	320.89	0.00	0.53	0.00