Spatial database Development for green house gas emission Estimation using remote sensing and GIS

Lilik Budi Prasetyo1, Genya Saito2, Katsuo Okamoto2, Haruo Tsuruta2, Ishizuka Shigehiro3, Ueda Shingo4, Upik Rosalina1, Daniel Murdiyarso5, Atiek Widayati5
1Guest Researcher of BIOTROP (1996-1998) and staff of Faculty of Forestry,
Bogor Agriculture University, Bogor-Indonesia
2Natinal Institute of Agro-Environmental Sciences, Tsukuba-Japan
3Forestry and Forest Products Institute, Tsukuba-Japan
4National Institute for Resources and Environment, Tsukuba-Japan
5South East Asia Impact Center, Bogor-Indonesia

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Abstract

Spatial digital database of Jambi Province, Indonesia from various sources of maps, remotely sensed imagery photos, field measurement and statistical data were developed using Geographical information System (GIS). The database result then were applied to make assessment of land-use/land cover change impacts on above ground carbon stock and soil surface flux of carbon dioxide (CO_2) nitrous oxide (N_2O) and methane (CH_4)

Introduction

Deforestation, conversion of forest into non-forest land use/land cover, especially in tropical forest area has been an international concern. It was estimated that tropical forest was deforested by 6-16.8 million hectares per year. (Grainger, 1993; Barbier et. all., 1991; Myers, 1994). Since forest hold the most carbon in terrestrial ecosystem, such changes give significant impact on the net increase of atmospheric carbon. In addition, land-use and land cover results in changes in greenhouse gases dynamics.

Greenhouse gases (CO_2, NO_2, CH_4) emission of soil is influenced by several factors such as land-used/land cover types, climatic factors, biological factors and physical environment factors. Emission measurements usually are conducted at a point location, therefore problem arise when emission estimation will be used for scaling up into a broader areas . The research aimed at the development of database to assist the regional estimation of aboveground carbon stock loss and soil surface green house gas emission changes caused by land-use/land cover changes using GIS and Remote Sensing. As a case study land-use/land cover change between 1986 to 1992 of Jambi Province, Indonesia will be evaluated.

Study Area Description

The study area is located in Jambi Province, between 0° 45' and 20°45' latitude south; 101° and 104°55' longitude east (Figure.1). The total area is 48,715 sq. km. It ranges from swampy coastal plains in the east to more than 1000 meters above the sea level in the western part. According to statistical data, in 1995 the population of Jambi was 2.18 Million and has increased more than two fold compared to 1971 data. (Bappeda Jambi 1995 and 1988).

Methodology

The research is initiated by the development land-use/land cover maps, and followed field measurement. Spatial database (land-use/land cover) construction was conducted in Forest Ecology and Remote Sensing Lab. Of Regional Center for Tropical Biology (Biotrop), and Remote Sensing Lab. of National Institute of Agro-environmental Sciences, Japan. Field measurements (above grounds biomass, and greenhouse gases flux) were conducted by Biotrop, Impact Center of South East Asia and National Institute of Agro-environmental Science, Japan.

Figure 1. Jambi Province, Indonesia

a. Land-use/land cover map construction

Spatial database (Arc/Info file) of Land-use/land cover were developed based on land-use/land cover maps in 1986 and 1992 at scale 1 : 250 000 published by Bitrop. These two maps were made based on visual interpretation of various remotely sensed imagery photographs such as Landsat MSSR and SPOT.

b. Bio-mass estimation (Aboveground carbon stock)

Weight of sample components of the tree and pole i.e. steams, branches, twigs, leaves and roots of primary forest, secondary and logged over forest were estimated by using equation developed by Kira and lwata (1989). Stern weight included stem barks, while weight of branches included twigs. For the sapling and seedling, the calculation of biomass per individual was obtained from the average weight of several saplings and seedling component was separated into leaf weight, stem weight and root tree with the number of tree per hectare. The same method is applied for poles, saplings and seedlings. Above ground biomass of the other land-use/land cover types were made based on literatures. To get aboveground carbon stock the biomass weight multiplied by factor of 0.5.

c. Soil Greenhouse gases flux measurement.

Flux of carbon dioxide, nitrous oxide and methane of soil surface were measured at various land-use/land cover types in order to obtain the estimates of diurnal emissions. The emission rates indicated by changes of methane concentration per unit time (dC/dt) were developed by plotting the analyzed air samples collected using closed-chamber method at 10-minute intervals. The Flux density is calculated as follows (Khalil et. al., 1991)

$$f = r\,V\,(M/Noa)\,(dC/dt) \times 6 \times 10^{-5}$$

f= Methane, Nitrous oxide or carbon dioxide flux ($mg/m^2/hr$), r = Air density (mol/m^3),
V= Chamber volume (m^3), M= gas molecular weight (g/mole), A= Chamber basal area (m^2)
dC/dt = emission rate (ppbv/minute), obtained from consecutive measurement.

c. Combine field data measurement and GIS spatial data.

Data on aboveground carbon stock and soil surface greenhouse gases flux were combined using Look Up Table (LUT) of Arc/Info. Estimation of total above ground carbon stock were calculated by multiplying the value by total area of each land-use/land cover. The same method was applied for calculating the total emission of greenhouse gases.

Result and Discussion

Land-use/land cover changes

Figure 2a and 2b. shows land-use/land cover patterns in 1986 and 1992, while Figure 2c is the overlay result. Quantitative comparison of the changes is presented in Table 1. Proportion of primary forest decreased from 19.3% to 12.5% in 1992. Further analysis of each land-use/land cover types is presented in Figure 3. It shows that about 24% of primary forest area were converted into logged forest , shrubs (fallow lands), cash crop plantation, cultivated and settlement areas. About 30% of logged forest were converted into shrubs, cash crop plantation, a mixture of cultivated and settlements. In the case of shrubs most of them were converted into a mixture between cultivated and secondary vegetation (40.3%), cash crop plantation (7.9%), logged forest (20.2%) and secondary forest. Of about 73% of Grasslands have changed into fallow lands (48.8%), a mixture between cultivated lands and secondary vegetation (20.7%).

Aboveground carbon stock changes

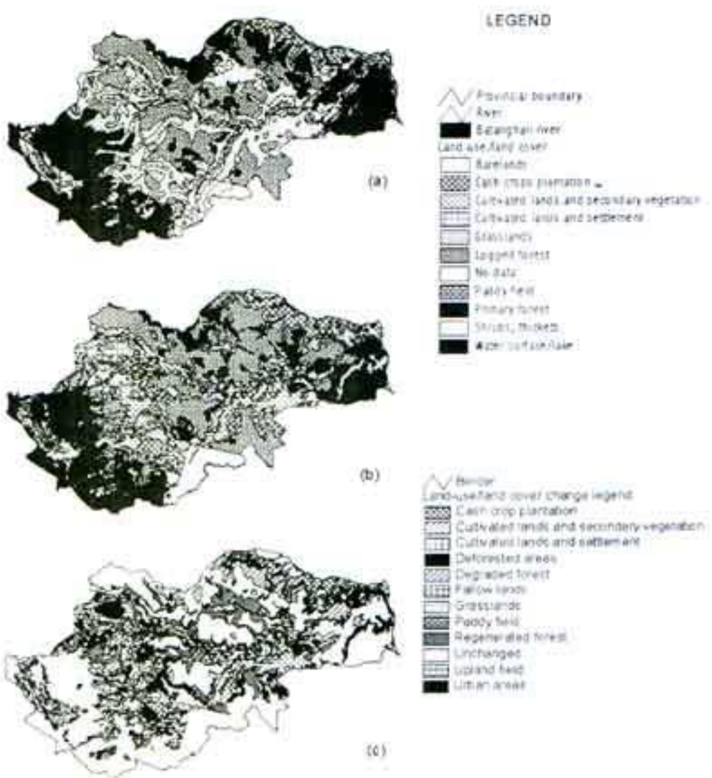
Aboveground carbon content estimation of each land-use/land cover were calculated by multiplying the area of each land-use/land cover with carbon stock per unit area. Table 1 above has showed the changes of above ground carbon due to land-use/lanc cover changes. Total above ground stock decrease from 6.16 x 108 ton in 1986 to 5.66 x 108 ton in 1992 or loss of about 0.50 x 108 ton within 6 years equal to 8.3 million ton per year. The loss of aboveground carbon was mainly came from primary forest conversion. IPCC have divided the loss of aboveground carbon content into on site and off-site release. These two categories were classified further into direct burning (fuel wood and slash and burn agricultural) and decomposition process release of unburned biomass (Houhton et. al., 1996). Thus the amount of carbon and greenhouse gas released to the atmosphere were depended on these processes. Estimation of the amount carbon and greenhouse gases release need yearly basis time series of spatial data and the information on commercial wood and fuelwood harvest, and burning efficiency data of each land-use/land cover type.

Land -use/Land cover	1986			1992		
	Area(sq.km)	% of total area	Total carbon (10^6ton)	Area(sq.km)	% of total area	Total carbon (10^6 ton)
Primary forest	165.21	33.91	416.89	12569.86	25.80	317.19
Secondary forest	0.00	0.00	0.00	1274.34	2.62	7.40
Logged forest	10022.39	20.57	155.53	12448.65	25.55	193.18
Fallow lands	9401.68	19.30	14.10	6072.66	12.47	9.11
Grasslands	535.99	1.10	0.32	523.19	1.07	0.31
Bare lands	3.67	0.01	0.00	3.67	0.01	0.00
Cash crops plantation	912.78	1.87	2.56	3303.17	6.78	9.25
Paddy field	1002.78	2.06	0.75	649.16	1.33	0.49
Upland field	0.00	0.00	0.00	235.84	0.48	0.18
Cultivated and Secondary Vegetation	7036.29	14.44	24.97	7933.39	16.29	28.16
Cultivated land and Settlement	1339.84	2.75	0.50	1630.68	3.35	0.61
Urban areas	0.00	0.00	0.00	132.17	0.27	0.00
Water surface/lake	42.41	0.09	0.00	42.27	0.09	0.00
No data	1896.60	3.89	-	1896.6	3.89	-
Total	48715.65	100.00	615.62	48715.65	100.00	565.88

Table 1. Land-use/land cover and above ground bio-mass changes between 1986 and 1992

Soil Greenhouse Gas emission changes

Green house gas flux of soil varies depend on type the site condition and season. The comparison below were made based on flux measurement conducted in November 1997 in several sites of Jambi Province. The calculation results of total flux based on 1986 and 1992 land-use/land cover data for major land-use land/cover presented in Table 2 and Table 3, respectively. Comparison of the total green house gases flux of the two periods of time could not be performed since there are still no information on greenhouse gases flux of soil surface under cash crops plantation and secondary forest. However, it seems that the conversion of natural forest will cause on the decrease of Methane gas absorption and induce the increase of Nitrous oxide flux emission.



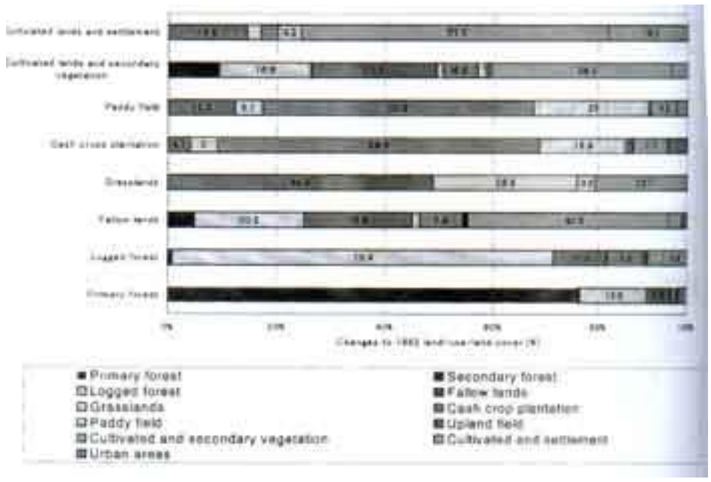


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Table 2. Total green house gas flux of Jambi Province based on 1986 land-use/land cover data

Land-use/Land cover	Soil surface flux of green house Gases in 1986					
	Flux of CO_2(mg/m_2/hr)	Total Flux of CO_2(mg/day)	Flux of N_2O(mg/m^2/hr)	Total Flux of N_2O(mg/day)	Flux of CH_4(mg/m^2/hr)	Total Flux of CH_4(mg/day)
Primary forest	425.00939	1.69×10^{14}	0.00806164	3.2×10^{9}	-0.0365	-1.45×10^{10}
Secondary forest	-		-	-	-	-
Logged forest	514.13489	1.24×10^{14}	0.01031502	2.48×10^{9}	-0.0431	-1.04×10^{10}
Shrubs/bush	580.71275	1.31×10^{14}	0.01996915	4.51×10^{9}	-0.0444	-1×10^{10}
Grasslands	603.61323	7.76×10^{12}	0.01101057	1.42×10^{8}	-	-
Bare lands	276.60000	2.44×10^{10}	0.00644000	567235.2	-0.0071	-621844.8
Cash crops plantation	-	-	-	-	-	-
Paddy field	-	-	-	-	-	-
Upland field	425.86029	-	0.00711683	-	-	-
Cultivated and Secondary Vegetation	473.61675	8×10^{13}	0.02030256	3.43×10^{9}	-0.0197	-3.33×10^{10}
Total		5.11×10^{14}		1.38×10^{10}		-3.82×10^{10}

Table 3. Total green house gas flux of Jambi Province based on 1992 land-use/land cover data

Land-use/Land cover	Soil surface flux of green house Gases in 1986					
	Flux of CO_2(mg/m^2/hr)	Total Flux of CO_2(mg/day)	Flux of N_2O(mg/m^2/hr)	Total Flux of N_2O(mg/day)	Flux of CH_4(mg/m^2/hr)	Total Flux of CH_4(mg/day)
Primary forest	425.00939	1.28×10^{14}	0.00806164	2.43×10^{9}	-0.0365	-1.1×10^{10}
Secondary forest	-	-	-	-	-	-
Logged forest	514.13489	1.54×10^{14}	0.01031502	3.08×10^{9}	-0.0431	-1.29×10^{10}
Fallow lands	580.71275	8.46×10^{14}	0.01996915	2.91×10^{9}	-0.0444	-6.47×10^{9}
Grasslands	603.61323	7.58×10^{12}	0.01101057	1.38×10^{8}	-	-
Bare lands	276.60000	2.44×10^{10}	0.00644000	567235.2	-0.0071	-621844.8
Cash crops plantation	-	-	-	-	-	-
Paddy field	-	-	-	-	-	-
Upland field	425.86029	2.41×10^{12}	0.00711683	40282396	-	-
Cultivated and Secondary Vegetation	473.61675	9.02×10^{13}	0.02030256	3.87×10^{9}	-0.0197	-3.76×10^{9}
Total		4.67×10^{14}		1.25×10^{10}		-3.41×10^{10}