Important subcategory of greenhouse gas emissions from degraded forestland: CO_2 emissions from biomass in a seasonal forest in Cambodia and soil organic matter in a peat swamp forest in Indonesia.

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Abstract: To isolate the major sources of greenhouse gasses in degraded forests, we selected two forest types: a degraded seasonal forest in Cambodia and a degraded peat swamp forest in Indonesia. The forests were classified into forest types, and for each forest type, we estimated the land area and mean carbon stock per unit land area for each carbon pool: e.g., aboveground and belowground biomass, deadwood, litter, and soil organic matter. The Tier 1 method in the IPCC's "Good Practice Guidance for Land Use, Land-use Change, and Forestry" and available data were used for our estimates. CO_2 emissions from biomass were considered important (89% of the total CO_2-e emissions) in the seasonal forest in Cambodia, while in the peat swamp forest in Indonesia, CO_2 emissions from soil organic matter were considered important (86% of the total CO_2-e emissions). Potential emissions were large, and so such estimates are invaluable in allowing for more effective overall estimates.

Key words: deforestation, ecosystem carbon stock, fire, forest degradation, REDD

I Introduction

REDD (Reducing Emissions from Deforestation in Developing Countries) (*7*) is a new mechanism to foster reduction of deforestation and forest degradation by inputting international support funds into developing countries suffering from deforestation and forest degradation. The amount of anthropogenic green house gas (GHG) emissions from deforestation and forest degradation needs to be predicted, reduced by anthropogenic effort, and monitored by MRV (measuring, reporting, and verification). Methods of monitoring GHG emissions from deforestation and forest degradation must be accurate; there must be less errors for each factor and all important factors must be covered. The major GHGs in forestland are CO_2, N_2O, and CH_4. We have developed a technology for detecting forest degradation and estimating GHG emissions using SAR indices in tropical forests. Both decreases in carbon stock and increases in GHG emissions are the main factors behind forest degradation, and monitoring carbon pools and GHG emissions, including those hardly monitored by remote sensing, is important. To collect

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inventory data sets of degraded forest ecosystems, we established two test sites, collected field data, and estimated the potential GHG emissions through forest degradation in dry-land forest (seasonal evergreen and deciduous forests) in Cambodia and wetland forest (peat swamp forest) in Indonesia. Using the findings, we clarified subcategories of important carbon pools and GHG emissions with a high priority on data collection in order to improve overall estimates.

This research was conducted as part of Program A-0802, which was supported by the Global Environment Research Fund of the Ministry of the Environment, Japan.

Ⅱ Materials and method

We classified the seasonal forest in Cambodia into evergreen forest and deciduous forest according to their floristic composition. The former includes mixed forests. The peat swamp forest in Indonesia was divided into four forest types according to stand development stages: old stage, young stage, stand initiation stage-1 (scarce deadwood), stand initiation stage-2 (plentiful deadwood). The land area of each forest type was measured by remote sensing. Landsat data were used for the Cambodian forest. Since the land area data for the Cambodian test site were unavailable, the nationwide ratios of evergreen forest and deciduous forest (calculated from Forestry Administration (*2*)) were used instead.

For the Indonesian test site, PALSAR data were used. We followed the Tier 1 method of the GPG-LULUCF (*1*). Main greenhouse gasses and subcategories in forestland selected by IPCC were shown in Table-1. Data of carbon stock and increases in GHG emissions were obtained in the test sites or other available sources. For the test site in Cambodia, biomass, deadwood, litter data in Kiyono et al. (*5*) and soil data from Toriyama et al. (unpublished) were used. For the test site in Indonesia, unpublished data were used for biomass, soil subsidence rates, and N_2O emissions by soil organic matter (SOM) mineralization. Sireger's soil carbon stock data in Miyagawa (*6*) were used. For other emission factors such as the combustion efficiency, default values in IPCC National Greenhouse Gas Inventories Programme (*1*) were used.

We made the following conditions and assumptions for the forests at the test sites based on our own data and estimated the GHG emissions in a period of ten years. Carbon gain was not considered, except in the understory, because the data were unavailable.

Seasonal forest: All trees were harvested and removed from the forestland in a period of ten years. The deciduous forest catches fire every year. At every fire, all the aboveground organs of the understory die and half are burned out. Half of the deadwood and litter are burned out. Soils at 0-30 cm depth are lost.

Peat swamp forest: Subsidence occurs in drained peat soils. The subsidence rate was estimated to be 2.4 cm yr^{-1} in the old stage and young stage forests, and 0.79 cm yr^{-1} in the stand initial stages. Fire occurs every five years. At every fire, 10% land of the old stage forest catches fire. For the young stage and stand initiation stages, 70% of the forestland catches fire. At every fire, half of the standing trees and understory die and are burned out, and the peat soil burns to a depth of 20 cm.

Ⅲ Results and discussion

CO_2 emissions from biomass accounted for 89% (72% in trees and 17% in understory) of the total amount, while 4% was from DOM (deadwood and litter), 3% from SOM, and 4% from the CH_4 from the burning biomass (Table-2, Fig.-1). A total of 425 Mg CO_2-e ha^{-1} emissions may occur in a period of ten years. The mean total emission was estimated at 11.6 Mg C ha^{-1} yr^{-1}. The emission rate was higher than the absorption rate by four carbon pools (aboveground and belowground biomass, deadwood, and litter) in degrading natural forest in Cambodia; ranged from -2 to 8 Mg C ha^{-1} yr^{-1} (calculated from Kiyono et al. (*5*)).

On the other hand, CO_2 emissions from biomass represented only 8% of the total amount in the peat swamp forest in Indonesia, while 4% was from DOM (deadwood and litter), 86% from SOM, and 1% from the CH_4 from the burning biomass (Table-2, Fig.-1). Another 1% of N_2O was from SOM mineralization. However, estimates of N_2O varied a great deal. Plus 1σ estimates were 4% of the total. A total of 878 Mg CO_2-e ha^{-1} emissions may occur in a period of years. The mean total emission was estimated at 23.9 Mg C ha^{-1} yr^{-1}. This is roughly equivalent to the ecosystem respiration measured by the eddy covariance technique in the Indonesian test site: 38.66 ± 0.35 Mg C ha^{-1} yr^{-1} (calculated from Hirano et al. (*3*)). The carbon absorption of the peat swamp forest remains unknown. However, since the biomass MAI of non-fast-growing tree forests on dry land was mostly less than 20 Mg ha^{-1} yr^{-1} (*4*), the emission rate was considered to be higher than the absorption rate of degrading natural forest.

IV Conclusion and future studies

The major sources of GHG emissions were biomass for the seasonal forest, and SOM and then biomass for the peat swamp forest. Such emission estimates are indispensable for more effective overall estimates. The sources of GHG emissions may differ by the type of anthropogenic intervention and the stage of forest degradation. More varied field data must be collected.

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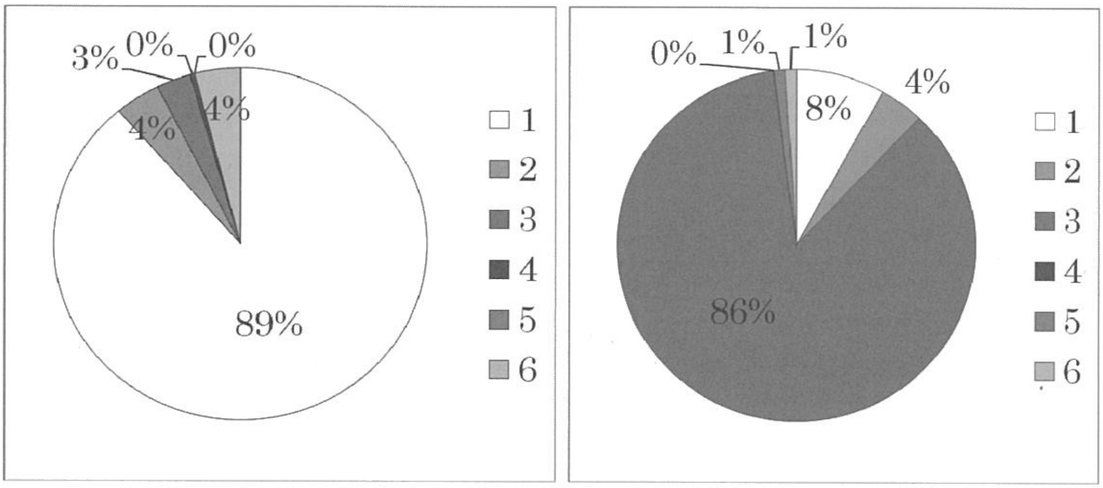

Fig.-1. The emission amount ratio of each subcategory to the total in the degrading forestland

1: CO_2 emissions derived from biomass, 2: CO_2 from dead organic matter, 3: CO_2 from soil organic matter, 4: N_2O from biomass burning, 5: N_2O from soil organic matter mineralization, 6: CH_4 from biomass burning.

Table-1. Main greenhouse gasses and subcategories in forestland

GHG	Subcategory
CO_2	AG and BG biomass Deadwood, Litter Soil organic matter (SOM)
N_2O	Fire SOM mineralization
CH_4	Fire

Table-2. Assessment of the greenhouse gas emissions of each subcategory in terms of the total potential CO_2-e emissions from degrading forestland at the test sites in a seasonal forest in Cambodia and a peat swamp forest in Indonesia

	Subcategory	Estimates with the project data (Mg-CO_2 ha^{-1} 10 y^{-1})	Importance
Dry land forest in the test-site in Cambodia			
CO_2	Biomass (aboveground and belowground)	377 (108-517)	89%
	Deadwood, litter	16 (0-19)	4%
	SOM	13 (5-22)	3%
N_2O	Fire	2 (0.3-3)	0.4%
	SOM mineralization	0	0%
CH_4	Fire	17 (3-31)	4%
	Total	425 (116-592)	100%
Drained peat swamp forest in the test-site in Indonesia			
CO_2	Biomass (aboveground and belowground)	60 (39-83)	8%
	Deadwood, litter	37 (29-43)	4%
	SOM	762	86%
N_2O	Fire	1 (1-1)	0.1%
	SOM mineralization	9 (0-37)	1%
CH_4	Fire	9 (7-11)	1%
	Total	878 (838-937)	100%

The Tier 1 method in Good Practice Guidance for Land Use, Land-use Change, and Forestry (*1*) and available data were used. Figures in parenthesis are mean ±SD.