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CAPACITY OF INDONESIAN FOREST AS CO_2 SINK: COMPARING AN INTACT PRIMARY FOREST OF LORE LINDU NATIONAL PARK CENTRAL SULAWESI WITH DEGRADED AND DRAINED PEATLAND FOREST IN CENTRAL KALIMANTAN

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ABSTRACT

This article compares the capacity of undisturbed tropical forest in absorbing CO_2 and acts as a net sink with the disturbed (drained) peatland forest acting as a net source. Undisturbed forest of Lore Lindu National Park (LLNP) absorbs substantial amount of CO_2 with low ecosystem respiration resulted in a net absorbtion reaching -970 gCm^{-2} year^{-1}. Data from a disturbed peatland forest in Central Kalimantan shows that although absorption was higher than the LLNP area ecosystem respiration of this drained peatland resulted in a big net emission reaching 447 gCm^{-2} year^{-1}. Recovery of the hydrological system of the area, reduced emission substantially.

Keywords: biomass**,** CO_2, peatland, tropical forest

INTRODUCTION

Tropical forests play a critical role on the global climate, through its ability to absorb and store a large quantities of terrestrial carbon. Grace (2004) showed that not only the stocks (biomass) and the Net Primary Production (supply for annual biomass increment) are largest in the tropical forest but also the CO_2 sink strength is highest compared to the other biomes. However, despite the above mentioned importance of the tropics as sink of CO_2, the distribution of sites for CO_2 continous monitoring and study is biased towards North America and Europe. Limited study sites for the tropics are from South America only and because of that, we are lacking empirical data to get a comprehensive picture on the absorption capacity of tropical forest ecosystems.

Indonesia was once considered as the third biggest emitter of CO2*e* in the world after USA and China, and LULUCF contribute 85 % of this emission (Peace 2007), with contribution from LULUCF 2563 MtCO_2e (million ton CO_2 equivalent). Despite the controversy of the information (as uncertainty is very high) the above assessment did not take into account the natural absorption of Indonesian vegetation accurately (if any), probably due to the unavailability or lack of data. Uryu *et al.* (2008) stated the status of Indonesian position in the world the same as in Peace (2007), with an absolute value a lot higher, adding 2000 MtCO2e from peat decomposition and fire. Again, in this report, where they concentrate on CO_2 emissions in Riau, potential sequestration by some plantations and natural forest are excluded.

The 2006 IPCC Guidelines, which is the recent UNFCCC standard guideline for conducting GHG Inventory, takes into account sequestration from all land categories. The reliability of the GHG emission and removals of the LULUCF depends on availability of data, those are the annual biomass increment and forest above ground biomass, which data are not easily available., because research are not well documented or available data are not in the format as needed by the calculation.

The synopsis below is written as an input for the Indonesian GHG Inventory assessment for LULUCF. It provides data on Net Primary Production (NPP), *Net Ecosystem Exchange* (NEE), Canopy Production efficiency, and biomass (and carbon stock) of intact natural forest Lore Lindu National Park (LLNP) in Central Sulawesi. In comparison to data of LLNP, measurement of CO2 fluxes from drained peatland forest in Central

Kalimantan is also shown. This information is published in *Springer Berlin*, 2007, *Global Change Biology*, 2007, Tree *Phyiology*, 2008 and BIOTROPIA, 2006.

THE LORE LINDU NATIONAL PARK IS A STRONG SINK FOR CO_2

A continuous CO_2 fluxes measurement in LLNP, is conducted through a collaborative long-term research program between Bogor Agricultural University , Tadulako University, Central Sulawesi with Gottingen and Kassel Universities of Germany under the framework of STORMA (*Stability of Rainforest Margin, SFB552*) Project, starting in 2001. Despte the old belief that primary or climax forest does not have the capacity to absorb CO_2, LLNP shows that the capacity is very high.

Within the period 2003-2005, it is found that the LLNP tropical forest is a very strong CO_2 sink, reaching -970 gCm^{-2} $year^{-1}$ (Figure 2). Yasuda *et al.* (2003), conducted a measurement of NEE in Pasoh forest in Malaysia, also reported a high sink in the range of −2.08 to −2.74 g C m^{-2} per day, equivalent to -7.6 to 10.0 $tonCha^{-1}year^{-1}$. The high productivity of this tropical forest is probably due to *"fertilization effect"* of the increasing atmospheric CO_2 concentration from a pre-industral value of 280 ppm to more than 380 ppm in 2006. A review of experimental studies by Norby *et al.* (1999) shows that a 300 ppm increase in atmospheric CO_2 concentrations stimulates tree photosynthesis by 60 %, the growth of young trees by 73 % and wood growth per unit leaf area by 27 %.

Malhi and Grace (2000) suggested in their perspective papers in TREE that productivity of tropical forest is increasing by approximately 0.3 % per year or 0.2 % for every 1 ppm rise in CO_2 concentration. Therefore, the very high sink for CO2 measured in tropical forest of Lore Lindu National Park, as mentioned above, is scientifically acceptable.

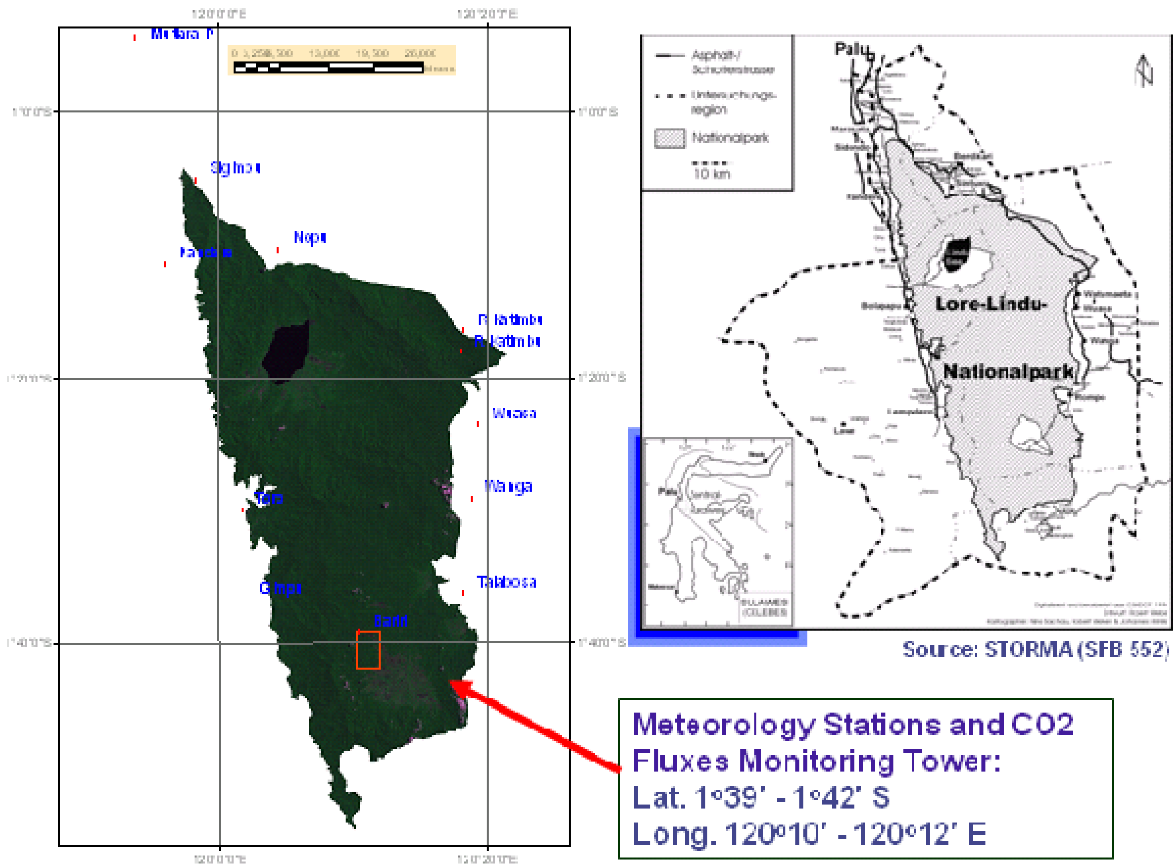
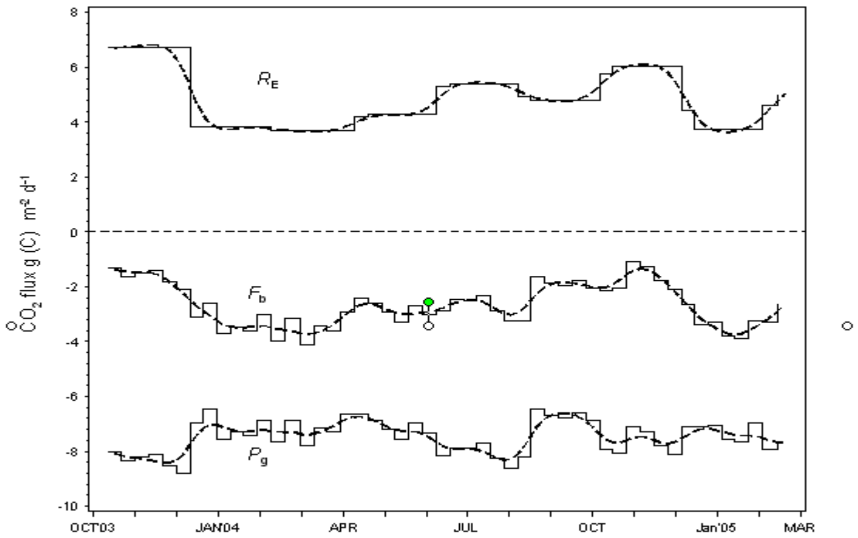


Figure 1 Sites for climate data, CO_2 and H_2O continuous measurement in Lore Lindu National Park, Central Sulawesi.

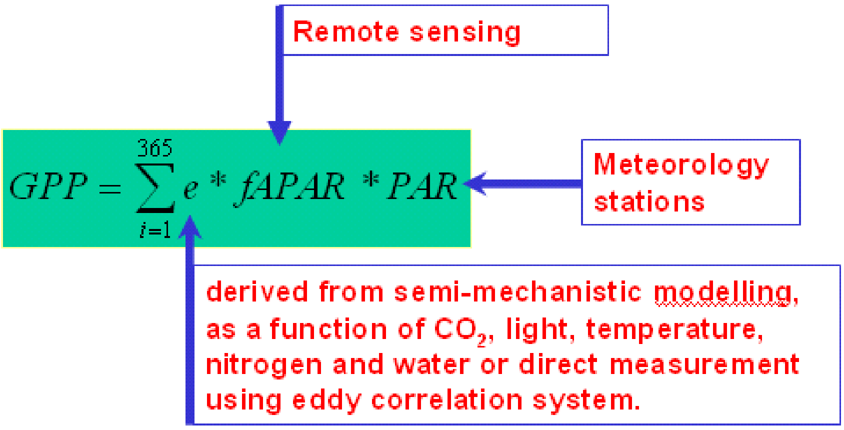


Annual accumulation (2003-2005):

- NEE/F_b : -970 gCm^{-2} year^{-1}
- GPP/P_g : -2730 gCm-2 year-1
- R_e : 1760 gCm-2 year-1

Figure 2 Daily ecosystem photosynthesis (Pg = GPP), respiration (R_e) and net ecosystem production (F_b= NEE) measured using an open path eddy correlation system in Lore Lindu National Park within the period of 2003 – 2005 (Ibrom *et al*. 2008). Based on this direct measurement, the whole area of LLNP of 217,991 ha is estimated to take up 2.1 MtCyear-1.

Modeling simulation was also conducted for this area (June 2006), scaling up from leaf to regional, utilizing photosynthesis process-based modeling, parameterized at the leaf level, integrated with vegetation index derived from remote sensing data. The simulation result showed that under the present condition, net absorption by forest canopy (Net Primary Production) is 13.30 tonC/ha/year. The relatively simple approach for the modeling carbon accumulation is as followed:



GPP = Gross Primary Production (CO_2 assimilation rate per year) (g m^{-2} year^{-1})
e = radiation use efficiency (g C MJ^{-1})
f_{APAR} = fraction of absorbed PAR
PAR = Photosynthetically active radiation (MJ m^{-2})

Based on Montheith (1977) and June (2006)

The ***e*** value is modeled using the Blackman-type radiation response function, taking into account the effect of radiation saturation, leaf area index and leaf physiology. Within the period 2003 – 2005, measurement of both CO_2 fluxes using eddy correlation system and PAR absorption by the forest canopy enabled us to calculate canopy radiation use efficiency (***e***) that can be utilized to estimate GPP. It was found that within a dry period (September 2004) gross photosynthesis reached 6.7 $gCm^{-2}day^{-1}$ and reached 8.5 $gCm^{-2}day^{-1}$ for most other productive months followed by radiation absorption of 7.5 and 9.4 $MJm^{-2}day^{-1}$. 90 % of radiation was absorbed by the canopy. For this area ***e*** was found to reach on average 1.10 $gCMJ^{-1}$, with maximum value of 1.5 $gCMJ^{-1}$ which is quite high.

DEFORESTATION AND FOREST DEGRADATION RESULT IN LOSS IN CARBON STOCK AND SINK

Unfortunately, deforestation and forest degradation, especially in the tropical region, especially Indonesia is happening at a very high rate, shown in Table 1, and it also happening around the boundary and enclaves of the national park of Lore Lindu. Due to high deforestation rates, it is likely that in Indonesia intact natural forests will survive in protected areas only. If Indonesia considered its protected areas to be supported by the global community through carbon compensation mechanism, we need to have an accurate measurement of how these protected areas absorb and store CO_2.

A recent aboveground biomass measurement was conducted in Lore Lindu National Park, closed to a village called Toro in Central Sulawesi with elevation 800-1140 meter above sea level. We measured the total aboveground biomass of different forest utilization, namely Forest type A (natural forest without major disturbance), Forest type B (forest extraction of small diameter timber), Forest type C (forest with extraction of large timbers) and Forest type D (cacao agro-forest plantation under remaining forest tree). We found that biomass and therefore, carbon stock of these type of forest are quite high, as shown in the following Table 2, higher than other places in the tropical region that have been reported. The total biomass recorded in Table 2 not include small tress with DBH < 10 cm, schrubs and soil cover plants, lychenes, debris, litterfall, roots, epiphyts etc, therefore the real total biomass and C-stock in this area should be higher than stated in the table.

It is important to note that degraded area, forest type C and D have a lower biomass and carbon stock. We also developed a correlation equation between NDVI (derived from remote sensing) with biomass and LAI which can be utilized for scaling up purposes.

Despite the high absorption of undisturbed primary forest in the Lore Lindu National Park in Central Sulawesi, a similar study site in Kalampangan (Figure 3), Central Kalimatan, shows that a disturbed peatland forest is a source of CO_2 due to drainage especially in dry year period.

For this site, source of CO_2 is quite high especially during El Nino year when the drainage canals are still open. However, with canal blocking (starting in 2002) and wetter years (2004) , source of emission reduced quite significantly (Table 3.). This result can be used as a base for mitigation action (through water management) and also as important information for green house gases inventory from the forestry sector.

Table 1. Deforestation in Indonesia 1990-2005

	Total Land Area, (x1000 ha)	**Area 2005 (x1000ha)**	**%**	**Annual Change 1990-2005 (ha)**	**Total Change 1990-2005 (%)**	**Annual Change 1990-2000**	**Annual Change 2000-2005**
Total forest cover change	190,457	88,495	48.8	-1,871,467	-24.1	-1.61	-1.91
Primary forest cover change		48,702	25.6	-1,447,800	-30.8	-2.06	-2.59

Note: Primary forest is defined as biologically important and old growth forests.
(Source: http://rainforest.mongabay.com/0801.htm)

Table 2. Biomass and carbon stock (ton/ha) of forest cover with different intensity in Lore Iindu National Park

Forest Cover Type	**Biomass (ton/ha)**	**C-stock (ton/ha)**
A (Natural Forest with traditional use (rattan extraction) but without timber extraction; closed canopy)	607	334
B (Natural forest with minor extraction of small trees not affecting the closure of the upper canopy layer)	603	331
C (Natural forest with major timber extraction, large canopy gap with canopy cover 40-60 %)	457	251
D (Agroforestry system, with remaining forest tree as shade to cacao tree)	203	112

(Source: Solicha *et al.* 2010).

Table 3. GPP, R*e* and NEE of degraded peatland forest in Central Kalimantan within the period 2002-2004

Year	**NEE ($gC\ m^{-2}\ y^{-1}$)**	**RE ($gC\ m^{-2}\ y^{-1}$)**	**GPP ($gC\ m^{-2}\ y^{-1}$)**
2002	447	3439	-2992
2003	282	3366	-3084
2004	211	3488	-3276
Mean	314±121	3431±61	-3117±145

(Source: Hirano *et al.* 2006)

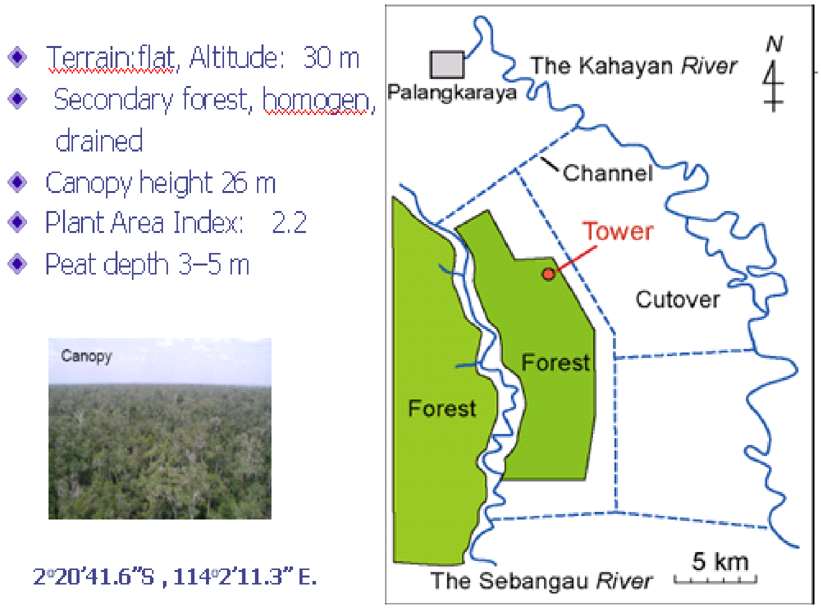


Figure 3 Site for continuous measurement of CO_2 and H_2O in Central Kalimantan, a research collaboration between JSPS (Hokkaido University), LIPI and IPB (Hirano *et al*. 2006).

CONCLUSION AND RECOMMENDATION

The area of the Lore Lindu National Park should be seen in a new light. These forests do not only host a great variety of endemic species and provide various ecological services but would also act as a valuable sink for atmospheric CO_2, and could probably be endorsed for carbon compensation under the REDD+ scheme.

Conservation and protection of the core area of the park should become a priority for future management. The key question that need to be answered would be, if the flux measurement which shows the very high CO_2 absorption by LLNP forest canopy is accepted by the scientific community, we need to conduct further studies to explain where the CO_2 is stored. Long-term forest plots offer great potential for direct monitoring and measurement of above and below ground biomass to answer the above question and to give a better data set for forestry inventory for Indonesia. The application of remote sensing needs to be explored further to easily scaling up the plot measurement to regional level. Further studies from peatland forest is needed, comparison between intact and degraded forest are required.

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