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# CARBON STOCKS AND EMISSIONS FROM DEGRADATION AND CONVERSION OF TROPICAL PEAT SWAMP FORESTS IN WEST KALIMANTAN, INDONESIA

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## SUMMARY

High rates of land cover change and deforestation in tropical peat swamp forests over the past few decades had been judged to increased peat decomposition rates and carbon (C) emissions from peatlands, yet this had been supported by little information. Our main objective was to estimate the C emission resulting from peat swamp forests (PSF) degradation into logged PSF (LPSF) and conversions into the adjacent wet shrub (WS) and oil palm plantation (OP) of the Pematang Gadung peat dome, Ketapang, Indonesia. We tested if degradation and conversion of PSF increase the peatlands‘ potential C emissions. C emission was measured using the C stock difference methods, comparing aboveground and belowground C stocks of LPSF, WS and OP with the PSF. PSF and LPSF have significantly higher aboveground C stocks (122 and 96 Mg C ha$^{-1}$, respectively) than WS and OP (12 and 7 Mg C ha$^{-1}$, respectively). Our results indicated that the loss of the PSF trees is a major driver of ecosystem‘s C loss. The significant loss of trees and other aboveground carbon stocks directed to a clear negative impact of land cover change on peatlands‘ role in sequestering atmospheric C. Potential CO$_2$ emissions of non-PSF sites were significantly higher than the PSF sites. Our study showed that PSF conversion to other land uses comes at a great cost in terms of significantly reduced function in sequestering greenhouse gas emissions. The high rates of deforestation of PSF, and subsequent high greenhouse gas emissions point to the relevance for inclusion of PSF in appropriate climate change mitigation and adaptation strategies.

***Keywords:*** *Land cover change; tropical peat swamp forests; oil palm plantation; CO$_2$ emissions; climate change.*

## INTRODUCTION

Tropical peatland ecosystem has among the largest ecosystem C stocks on earth (Page et al., 2011). Tropical peatlands comprise about 10% (44 Mha) of the global peatland (400 Mha), in which Indonesia alone has about 50% (21 Mha) (Murdiyarso et al., 2009). Indonesia contains the largest area of peat in the tropical zone, where about 6.8 Mha are located in Borneo island (Radjagukguk in Rieley and Page 1997; Murdiyarso et al., 2009). Undisturbed tropical peatlands have been shown to store huge quantities of carbon (C) in peats ranging from 824 to 7,888 Mg C/ha (Murdiyarso et al., 2009; Warren et al., 2012). The C stock of tropical peatlands range from 81.7 to 91.9 Gt or about 15-19% of global peat carbon stock (610 Gt), in which Indonesia contain 57 Gt (Verwer & Meer 2010; Page et al., 2011).

Rates of land cover change in tropical wetlands over the past few decades have exceeded that of upland tropical forests (Hergoualc‘h & Verchot 2011). Recent estimate suggests that Indonesia shows highest increase of forest loss that is more than 1,000 km$^2$/year (Hansen et al., 2013). Deforestation and forest degradation, including forest conversion to oil palm (*Elaeis guineensis)* plantations, are the main human disturbances to peat forest ecosystems (Fearnside 2000). Peat forests mainly converted into oil palm, food crops and timber plantation (Murdiyarso et al., 2009; Hergoualc‘h & Verchot 2011). Conversion of tropical peat forest involves cutting trees, burning and/or developing drainage canals (Anshari et al., 2010; Hooijer et al., 2010). This conversion likely increases peat decomposition rates and C emissions from peatlands (Kauffman et al., 2009; Murdiyarso et al., 2010; Hergoualc‘h & Verchot 2011). We need to understand impacts of land cover change on the dynamics of peat forests‘ C in order to inform decision making in climate change mitigation and adaptation strategies.

Emission from peatland in South East Asia has never been estimated using the C stock difference method in a synchronic experiment (Hergoualc‘h & Verchot 2013). This study is among the first that combines intensive field measurements of tropical peatlands‘ carbon stocks to provide accurate estimates of the fate of stocks and emissions.

Our main objective of this study was to estimate the changes on carbon stocks and emissions resulting from forest degradation and conversions of peat swamp forests into the adjacent wet shrubs and oil palm plantations of the Pematang Gadung peat dome, Ketapang, Indonesia. While total carbon stocks information has been reported for the peat swamp forest regions of Kalimantan (Murdiyarso et al., 2009) and of Sumatera, Indonesia (Suwarna et al., 2012) we know of no studies that have measured total carbon stocks associated with the land cover change and their emissions.

Our specific research questions included: What are the carbon stocks of the peat swamp forests (PSF) of the Pematang Gadung peat dome? How do they differ between relatively intact PSF and logged PSF? What are the carbon stocks of wet shrubs (WS) and oil palm plantations (OP) that were formed on sites previously occupied by PSF? And finally, what are the potential emissions that could arise from degradation of PSF to LPSF and from conversion of PSF to WS and OP?

## METHODS

The study area is located in Pematang Gadung, Ketapang, Indonesia in the province of West Kalimantan. The Pematang Gadung is a coastal peat dome (34,651 ha) in between the Pawan and Pesaguhan Rivers that flow on the northern and the southern end of the peat dome, respectively. The rainfalls in the region averages 2000 mm per year and mean annual temperature is 27.5°C. Elevation ranges from 11-22 m above sea level.

All forests (5 relatively intact - Peat Swamp Forests/PSF and 5 highly - Logged Peat Swamp Forests/LPSF) were transition between peat swamp and low pole forests with a mean canopy height of 15 m (Page et al., 1999) and occurring around the center of the peat dome. In addition to the forests, we sampled five wet shrubs (WS) and five oil palm (OP) smallholder plantation. The OP plantations were surrounded by the WS and LPSF. Based upon observation on satellite imageries and interviews with local people, the forests were logged since about 25 years before sampling (in 1988) and wet shrub were formed about 19 years before sampling. All wet shrubs had frequently been burned during the dry month‘s period. The five oil palm plantations were one (1), two (2) and three (2) years old, that were established following burning for land clearing and canalization.

We selected research sites based on field observation, discussion with local experts and analyses on some Landsat images. Considerations include availability of PSF and other land cover types that were previously converted from the PSF, as well as sites‘ relative position within the peat dome. We studied the ecosystem carbon stocks and structure of 20 different coastal peatlands including five PSF sites, five LPSF sites, five WS sites, and five OP plantations. In order to ensure the sequential changes of land cover types (from forests to WS and OP plantation), we paired each forest site with the others in a close distance. We have five pairs of cover types (PSF – LPSF – WS – OP).

Ecosystem C stocks (above-and belowground) were measured, in each site, following methodologies outlined by Murdiyarso et al. (2009) and Kauffman and Donato (2012). Nested to each forest, wet shrub and oil palm site, six plots were established 30 m apart along a 150 m transect positioned in a perpendicular direction from the riverine ecotone and drainage canal. At each plot, we collected data necessary to calculate total C stocks derived from standing tree biomass, downed wood (dead wood on forest floor), understorey and litter fall, and peat to the depths of the mineral soils.

## RESULTS

Aboveground C stocks ranged from 5 Mg/ha in the OP site to 139 Mg/ha in the PSF site. There were significant differences when comparing the PSF to the LPSF, WS and OP sites. The OP was the lowest in aboveground C stocks, with a range from 5 to 11 Mg/ha. In peat swamp forests there was high variation in the total aboveground carbon pools, with a range of 103-159 Mg C/ha among PSF sites and 57–90 Mg C/ha among LPSF sites.

Mean peat carbon stocks at PSF was 3925 Mg C/ha, at LPSF was 3,784 Mg C/ha, at WS was 3,372 Mg C/ha, and at OP was 3,655 Mg C/ha.

The mean ecosystem carbon stock for the PSF sites was 4,024 Mg C/ha, the LPSF was 3,768 Mg C/ha, the WS was 3,147 and the OP was 3,135. At PSF sites, peat carbon pools comprised a mean of 96 % of the total ecosystem pool with range of 95% at the PSF2 site to 97 % at the PSF4 site. At LPSF sites, peat carbon pools comprised a mean of 97 % of the total ecosystem pool with range of 93% to 98%. At all WS and OP sites, peat carbon pools comprised a mean of 99% of the total ecosystem pool.

We examined potential greenhouse emissions on a $CO_2$ equivalence ($CO_2$e) basis arising from conversion of PSF to LPSF, WS and OP. In 25 years, the mean potential emission from PSF conversion to LPSF was 938 Mg $CO_2$e $ha^{-1}$. The mean potential emission from PSF conversion to WS was 3,215 Mg $CO_2$e $ha^{-1}$. The mean potential emission from PSF conversion to OP was 2,132 Mg $CO_2$e $ha^{-1}$.

## DISCUSSION

Our results indicated that the loss of the PSF trees is a major driver of ecosystem‘s C loss. The significant loss of trees and other aboveground carbon stocks directed to a clear negative impact of land cover change on peatlands‘ role in sequestering atmospheric C.

We found that there was a mean loss of 3,215 Mg $CO_2$e $ha^{-1}$ and 2,132 Mg $CO_2$e $ha^{-1}$ from the peat carbon pools when PSF are converted to WS and WS+OP, respectively. In contrast, few changes in soil carbon were noted with upland tropical forest conversion. For example, Kauffman et al. (1998) did not find significant differences in either soil C concentration or mass when comparing surface soil carbon in Amazon tropical forests and the converted areas.

Kauffman et al. (2015) argued that the loss in carbon stocks from mangrove conversion was 7-fold that of emissions from dry forests and 3-fold greater than emissions from Amazon forest to pasture conversion. This study shows that the carbon stocks lost from PSF conversion to wet shrub, dominated by grasses and ferns, is significantly greater than emissions from Amazon forest and mangrove to pasture conversion (1,464 Mg CO2e $ha^{-1}$ for 30 years).

We have reported that C emission occurs in peatland ecosystem when the peat swamp forests are degraded and converted into LPSF, WS and OP. This is important because at the peat dome scale, the annual emissions of LPSF, WS and OP are equal to an annual loss of many hectares of PSF‘s standing C stock.

## CONCLUSION

Our study shows that PSF conversion to other land uses comes at a great cost in terms of large quantities of greenhouse gas emissions. The large carbon stocks, high rates of deforestation of PSF, and subsequent high greenhouse gas emissions points to the relevance for inclusion of PSF in nationally appropriate climate change mitigation and adaptation strategies. Tropical peatlands may be bundled with national level mitigation actions and participated by relevant stakeholders.

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