Jurnal Silvikultur Tropika
Vol. 07 No. 3, Suplemen Desember 2016, Hal S24-S28
ISSN: 2086-8227

# VARIATION OF FOREST STRUCTURE AND BIOMASS ALLOCATION AMONG DEGRADATION LEVEL OF WEST KALIMANTAN PEATLAND FOREST

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## ABSTRACT

Tropical peatland forests in Indonesia are facing a lot of pressure, resulting increased deforestation and degradation of intact forests. Both natural and anthropogenic cause of changes – concentrated in Sumatra and Kalimantan, Indonesia – has been reported as 3.4% y-1 from 1990 – 2010. Currently, only ~ 41% to 44% of the original peatland forests of Kalimantan left. As a result of both changes, degraded peatlands have altered their balance on their natural conditions and roles, since degradation of forest cover is often a complex process with their own of ecological recovery. A study has been executed to explore the effect of forest degradation on forest structure and their biomass allocation in coastal peatland forest of Kubu Raya, West Kalimantan. Forty eight of a 50 x 50 m sized plots with variety of degradation level were assessed for their tree structure, density, stand biomass, and basal area and compared. Results show that forest degradation shifted tree diameter 10-20 cm dominance on their biomass stocks to larger trees (>20 cm) and smaller one (5-10 cm). Forest structure seems in a good and normal shape from small tree to large one. It is indicated that high degraded forest demonstrate a decline its biomass allocation, tree density per hectare, basal area on each level of forest structures.

Key words : basal area, peatland forest, stand biomass, tree structure, tree density.

## INTRODUCTION

Land use and land cover changes by forest degradation or clearing tropical forest for conversion or expanding urban development, are often disturbing ecosystem functions and degrading environmental conditions (Achard *et al.* 2002) (Foley *et al.* 2005) (Miettinen *et al.* 2011) and, consequently, they result in major contributions to global greenhouse gas emissions (Soares *et al.* 2006) (DeFries *et al.* 2007) (Skutsch *et al.* 2007). The increased of forest degradation and forest land conversion to agricultural lands or urban areas accelerates this release of organic carbon to the atmosphere (Mitra *et al.* 2005). In addition, land use change will also impact and alter terrestrial ecosystem processes (Miettinen and Liew 2011).

Peatland forest is one of forest types in tropical area that is also in huge pressures. (Margono *et al.* 2012) reported during the last two decades of 1990-2010 there was 7.54 Mha forests were changed and and additional 2.31 Mha were degraded. The increasing scarcity of available land resources in mineral soils, advanced land conversion technology and continuously rising demand for forest and agricultural products have led to a rapid increase in peatland conversion and degradation. Hoojiers *et al.* (2010) and Couwenberg *et al.* (2010) stated that those activities significantly increase carbon emissions, yet also disturb ecosystem functions invariably, both directly because of reduction of forest density and acceleration in peat oxidation and indirectly by making the ecosystems more vulnerable to yearly fire activity (Curran *et al.* 1999) (Siegert *et al.* 2001).

There are numerous functions of tropical peatlands ranging from regulation of water flow to providing refuge for endangered animal species (Rieley and Page 2005). However, the impacts of forest degradation on peatland forest in-situ condition such as forest structure and composition and their roles in maintaining carbon in their biomass are not stated clearly and how this condition affect the process within the forest changes is interesting to be investigated. It was reported that observation on tree canopy with Geoscience Tree Altimeter System found a significant structural difference between primary intact and primary degraded forests (Margono *et al.* 2012). Increasing forest degradation has been shown to impart greater microclimate change on in the forest floor (Barton *et al.* 1989) (Proe *et al.* 2001) (Asbjomsen *et al.* 2004). These results imply that in tropical peatlands, forest degradation and land cover change - with corresponding alterations of soil microclimate (e.g., temperature, CO2, light, humidity) - will influence forest dynamics. Therefore, this research aims to investigate the impacts of peatland forests degradation (i.e., canopy gap levels) on their forest structure and their role on allocated forest biomass.

## MATERIALS AND METHODS

This study was conducted in an ombrotrophic, peatland in Kubu Raya district, West Kalimantan, Indonesia ($0^0$13′ S and109$^0$ 26′ E, ~ 4 m a.s.l.; ~3km from northern perimeter of Kuala Dua_Rasau Jaya peatland). Forest structure, basal area and their biomass allocation condition had been assessed in 12 ha block of peatland forest. From our peat surveys and studies in West Kalimantan, we determined that this study area was highly representative of West Kalimantan coastal-peatland areas as the overwhelming majority of coastal peat areas had been selectively-logged. Our pre-survey classified this forest degradation by canopy gaps classes: low, intermediate, and high degraded (gaps < 30%, 30-70%, and >70% consecutively. Under this class, we measured forest structure, basal area, and their biomass stocks. We refined the canopy coverage measures with Leaf Area Indeks (LAI) readings. Based on our preliminary assessment on peatland forest tree canopy, there were 3 classes of canopy opening which lead us to class them into 3 classes of forest degradation as mentioned above. Across study area, trees diameter >10 cm were surveyed by assessing 48 of a 50 x 50 m plot and registered all trees diameter > 5 cm within each plot. Seedling measurements were subsampled systematically nested within each 50 m plots. All trees within the sampling plots were mapped, tagged, identified to species or at least to genus.

Transforming tree diameter into accurate biomass estimates requires application of an appropriate allometric equation (Clark *et al.* 2001). We follow (Paoli and Curran 2007) (Astiani *et al.* 2015) to estimate aboveground biomass using the moist forest equation of (Chave and Andalo 2005) that also incorporates specific wood densities. In addition, LAI, microclimate and soil properties were also investigated. Throughout the estimation of stand structure, basal area, and biomass, data are presented as means and standard errors (SE) unless otherwise noted. To test for differences among peat degradation levels/canopy gap classes, ANOVA analyses were used and then proper pairwise comparisons were applied (e.g., Tukey Procedures). This procedure was also used to test for differences among forest canopy classes with several environment factors (peat temperature (ºC), peat water vapour ($H_2O$ mmol mol-1), peat CO2 concentration (ppm), peat water content (%), ambient temperature (ºC), amount of throughfall (mm), and Leaf Area Index measurement reading ($m^2/m^2$).

## RESULTS AND DISCUSSION

### Peatland Forest Structure among Degradation Levels

This peatland ecosystem is presented here best reflect degraded or converted peat forest parcels and provide a realistic condition of general peatland forest in Indonesia at present. The distribution of forest canopy gap explain that there was various condition of present peatland forest. The canopy closures distribution on each measurement ranging from 0.5% to 92% and within plot average range was 11% to 87% (Figure 1a and 1b).

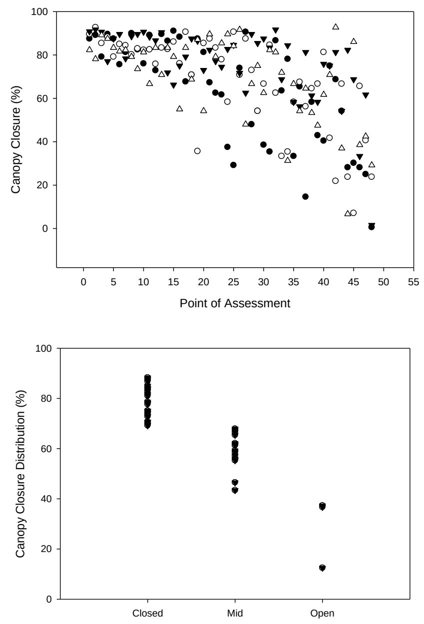


Figure 1. a) Peatland forest overall canopy closures distribution (%) within study area; b) Canopy closures distribution within each canopy coverage class (%)

Forest structure among degradation levels and tree-diameter distribution demonstrated that larger tree (diameter >20 cm) show no difference on their density. However the smaller tree generate significant different among them. High degraded peatland forest significantly reduced tree density compare to low and mid degraded one tree diameter 10-20 cm and 5-10 cm (Figure 2). This results indicate that forest degradation impacted the natural succession of younger trees, while for larger trees, there were no significant effect. Our previous assessment on new seedlings also support the results (Figure 3; (Paoli and Curran 2007). Viewed from forest structure, this peatland forest is in good stage of succession after disturbance as logged over area that was low impact harvesting in 2003-2004 for transmigrants housing near the forest. The tree density distribution of large to small trees demonstrate that this forest is in good state of their succession. Since the larger trees (diameter > 20 cm) were logged on those event, they showed similar trend of density, while smaller trees adapted to new forest condition post harvesting.

The stand density over study area, under low, intermediate, and high degraded peatland forest were consecutively 87.0 ± 6.1, 86.2 ± 8.5, and 66.7 ± 6.7 trees/ha for diameter > 20 cm, 411.1 ± 17.2, 340.2 ± 31.5, and 180.0 ± 47.4 trees/ha for diameter 10-20 cm, and 1 172.9 ± 52.7, 1 094.1 ± 76.2, and 666.7 ± 159.3 trees/ha for trees diameter 5-10 cm. There were decreases of ~23% on trees diameter > 20 cm, ~56%, on diameter 10-20 cm, and ~43% on 5-10 cm. The seedling and sapling population density under low, intermediate, and high degraded peatland forest are 26 436; 25 241; and 16 467 seedlings/ha consecutively. However, the data imply that forest degradation influence the young trees density. High level of forest degradation reduced their seedling population to 55% when the forest are highly degraded from relatively low degraded condition (Figure 2 and 3).

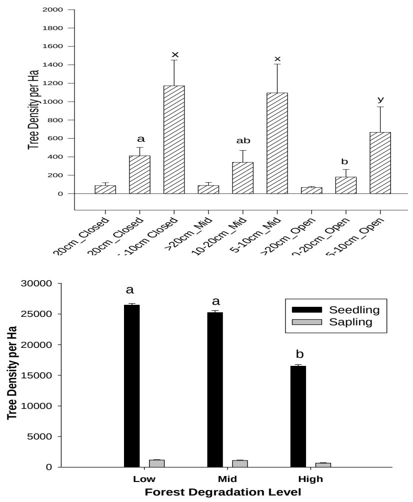


Figure 2. a. Tree Density distribution showing recent peatland forest structure among degradation levels; b. Seedling distribution among peatland forest degradation levels (Brown 1993).

**Peatland Forest Basal Area Distribution**

There was consistently a shift of stand basal area under various degradation levels. Mean basal area of study area was 17.0, 16.7, dan 11.2 $m^2$ consecutively for closed, mid, and low degraded peatland forest. Distribution of each diameter class and their statistical mean separation analysis is presented in Figure 3. Basal area shows the tree occupation within the unit area. This secondary peatland forest is mainly has lesser stem area compared to lowland forest.

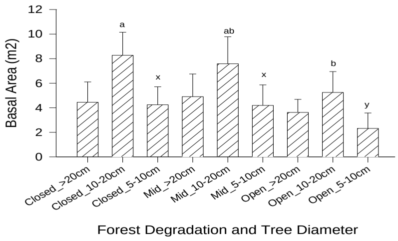


Figure 3. Forest basal area among forest degradation levels and tree diameter classes

**Biomass Allocation among Forest Degradation Levels**

Peatland forest comprised of approximately 157.3, 158.1, 132.2 ton/ha consecutively for low, mid, and high degradation. There were decreased ~3.5 to 13.6 ton/ha biomass reduction on trees > 10 cm. On the contrary, smaller trees (< 10 cm) increased 4.6 ton/ha when forest being degraded relatively low degraded forest into high level or when canopy gap is increase into larger than 70%.

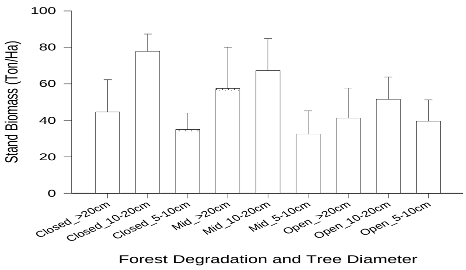


Figure 4. Biomass allocation per ha of a) tree diameter > 5 cm; b) seedling of peatland forest

**Peat Environmental Conditions**

We collected data on Leaf Area Index among peat temperature, peat surface water vapor, peat water content, soil surface $CO_2$ concentration, ambient temperatures, and amount of precipitation under 3 canopy levels (forest degradation). Repeated Measures ANOVA showed that several microclimate conditions under forest degradation levels were invariably significantly different.

The distribution of LAI was quite wide within degraded forest yet when classed into degradation levels following canopy closures measurement, there were significantly difference among them. Low and mid degraded forest was 2.6 and 2.3 $m^2/m^2$ significantly higher than high degraded one. The mean LAI distribution were 4.53 ± 0.13, 5,22 ± 0.20, and 1.95 ± 0.71 $m^2/m^2$ consecutively for low, mid, and high degraded forest (Figure 5a). Further analysis to check the correlation between forest canopy coverage and LAI found that there was positif correlation between them (r = 0.41, p = 0.004). The regression equation of the 2 factors is Canopy Closure = 41.286 + (6.388 * LAI) with n = 48; r = 0.407, r2 = 0.17, and SE = 14.03 (Figure 5b). The equation explains that within the range of this forest condition, the increasing of 1 $m^2/m^2$ LAI will equal to the depleting ~6.4% canopy coverage.

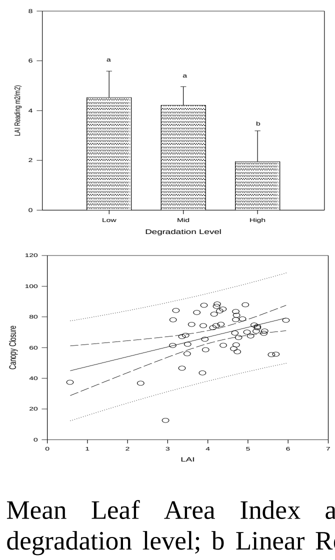


Figure 5.a. Mean Leaf Area Index among forest degradation level; b Linear Regression and correlation bertweenLAI and canopy coverage

Results show that forest degradation reduced tree densities on forest floor. Fewer seed sources under high degraded forest because of lesser large trees could be one of the reasons why regeneration here was not as dense as under low or intermediate degraded forest. Surprisingly, seedling and sapling biomass was relatively high if compared to the density in mineral tropical forest (Brown 1997) Our prior study demonstrated that this peatland forest total biomas was ~128 ton/ha (Astiani 2014). Thus, peatland forest contribute to 86% of total biomass while young trees comprised the rest.

Our results indicate that larger gaps reduce tree density except for sapling stage. It is indicated that under high degraded forest is demonstrating potential recovery of this degraded peatland forest (Berenguer *et al.* 2014) and in general, this peatland forest has relatively adequate young tree to fulfill peatland forest regeneration. This phenomenon need more attention in order to reduce the loss of higher biomass in the future time. Some species might be favor to and some might be not tolerate to the alteration of site condition due to the canopy gaps changes.

## ACKNOWLEDGEMENTS

Our appreciation to people in Kubu Raya District of West Kalimantan peatland area, who allowed us to assess their community forest and assisted us with their works and times to help us to collect some data. We thanks to Yale University, that allowed us to have this study in between our other large goals in studying peatland carbon dynamics in West Kalimantan. We thank you all other poeple who participated in this study.

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