**BIODIVERSITAS**
Volume 17,Number 1,April 2016
Pages: 102-109

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d170115

# Tropical peatland tree-species diversity altered by forest degradation

**DWI ASTIANI**
Faculty of Forestry, Tanjungpura University. Jl. Prof. Hadari Nawawi, Pontianak 78121, West Kalimantan, Indonesia. Tel.: +62-561-765342, 583865, 732500, Fax.: +62-561-765342, email: astiani.dwi@gmail.com

Manuscript received: 19 December 2015. Revision accepted: 12 February 2016.

**Abstract**. *Astiani D. 2016. Tropical peatland tree-species diversity altered by forest degradation. Biodiversitas 17: 102-109.* Indonesian experienced relatively high deforestation and degradation. The forests degradation could bring the forests into a temporary or might be permanent destruction not only in forest vegetation density and structure, but also in species composition. A study had been carried out to examined the impact of peatland forests degradation on their species diversity composition in Ketapang, West Kalimantan peatland forest. Stratified random sampling was used to distinguished forest degradation class (low, intermediate and high degradation levels) based on the differences in spectra image and confirmed with field checking by measuring forest canopy opening to measure the degradation levels. Six to twelve of a 20x100m plots were established to sample tree structure and composition distributed along peatland landscape. All trees species diameter >5cm was registered an species identified. Results indicated that tree diversity was significantly reduce due to forest degradation, in low, intermediate, and high degraded forest were 82, 72, and 48 consecutively. Forest degradation is not only resulted more than 50% of important species loss in high degraded peatland forest but also reducing ~40% tree abundance. Ten species were found in high degraded forest, e.g., *Calophylum inophyllum*, *Cyathocalyx biovulatus*, *Neoscortechinia kingii*, and *Eugenia cerina,* were not present in low degraded one. The species composition and abundance shifting due to forest degradation should be considered on peatland forest management to hinder permanent species loss.

**Keywords**: species abundance, species composition, tree species loss

## INTRODUCTION

Tropical forest is regarded as one of the largest biodiversity which has rich array of plants, animals, and microbial life form and plays an important role in ecological system due to it large area of coverage, which are important to maintain their function in biosphere (Dirzo and Raven 2003). It also provides habitat biodiversity, hydrology regulator, and carbon storage and the ecosystem recently deserve special attention because of continuing considerable destruction (Celine et al. 2013). While the tropical forests are facing the environmental problem, many aspects of the issue had been overlooked until recently. The tropical forest degradation was not only clearing large area of forests (i.e. with selective logging)- but the altering and replacing of old growth forest also happened spreadly (Foley et al. 2007).

Forest and non forest term are not adequate for describing forest in a landscape, yet until recently it is used to draw the condition of tropical forest. Recent forest ecosystem is further dynamic and a complex system because they experience logging, opening landscape, regrowth, mortality which result more complex mosaic of intact rain forest and recovering secondary forest (Nepstad et al. 1999; Cardille and Foley 2003).

Indonesian rainforest plays an important role in as home to third most extensive humid tropical rainforest and account for 2.3% of global forest cover (FAO 2010). It contains high floral and faunal biodiversity (Ministry of Forestry 2011), yet about 27% of Indonesian population depends directly on these forests for their livelihood. Consequently, the forest experience relatively high deforestation and degradation. The deforestation rates of intact forest in Southeast Asian tropical peatlands-concentrated in Sumatra and Kalimantan Indonesia-has been reported as 3.4% $y^{-1}$ from 1990-2010 (Miettinen et al. 2011; Achard et al. 2002).Similar to the global condition, tropical forests in Indonesia are in a lot of pressure mainly due to anthropogenic activities such as logging causing forest disturbances and degradation (Margono et al. 2012).

Land cover change pressures and rapid deforestation and degradation were also occurred in West Kalimantan peatland forests. The forest type extends about 1.58 million ha in this province however only around 45% of the forest is still remaining with variable forest conditions. The forests degradation may alter the forests into a temporary or might be permanent destruction in forest vegetation density and structure, species composition (Lambin 1999; Grainger 1993) and the condition could lead to reduce their productivities and ecological role in the landscape.

In addition, land use change will also impact effects and alter terrestrial ecosystem processes (Miettinen et al. 2011).Thus, land conversion has and will likely continue to alter the emissions of greenhouse gases (IPCC 2011; Carlson et al. 2012, 2013). However, the impacts of forest degradation on peatland forest in-situ condition such as micro climates and forest in state condition is not clearly stated and how this condition affect the process within the forest changes matrix is interesting to be investigated. The occurrence of various forms of peatland conversion and degradation is well known. Yet the impacts of forest degradation on forest dynamics is also not clear. To investigate the impacts on the alteration of forest tree composition and their dynamics, a study had been carried out to examine the impact of peatland forests degradation on their species diversity composition in Ketapang, West Kalimantan peatland forest.

## MATERIALS ANDMETHODS

### Study sites

This study was conducted in an *ombrotrophic*, peatland in Riam Berasap and Tulak of Ketapang District, West Kalimantan, Indonesia ($110^0$ 6’ 0” E to $110^0$ 18’ 0” E and $1^0$ 21’ 0” S to $1^0$ 31’ 0” S ~ 4 m asl.; Figure 1; in Astiani 2012). Peat depth range 2-7.5 m. Mean annual rainfall was 2892 mm ± 17 mm with 172 ± 8.2 rain days per year (compiled from Ketapang airport, Rahadi Usman weather station, West Kalimantan; in 200-2014). This area had been low-impacted logged 8-10 year ago and naturally regrowth. However, the forest coverage and condition was left in various conditions in term of their canopy coverage and tree density. The peatland forest in this area were distributed to four blocks: Riam Berasap (RB), Manjau (MJ), Marsela (MS), and Tulak (TL) Peat Forest. These areas were chosen based on the indication of peat land area derived from satellite image interpretation and soil map.

From our peat surveys and studies in West Kalimantan (Astiani 2014), 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 and transported with 'sepeda' or 'kuda-kuda' system along the skilled road (Figure 2.A and 2.B).

### Sampling approaches for collecting data

Forest tree biodiversity was conducted following Astiani (2012) survey using stratified sampling based on the differences in spectra of Land Sat Image according to the land cover change or forest cover types. Based on overlaying of Landover Map 2009 and SRTM Spectra with 90 meter Resolution, this area is classified based on the canopy closures and land cover types in the area were grouped into: low, intermediate, and high degraded peatland forest. Field checkings were conducted to measure tree canopy opening using Densiometer measurement.

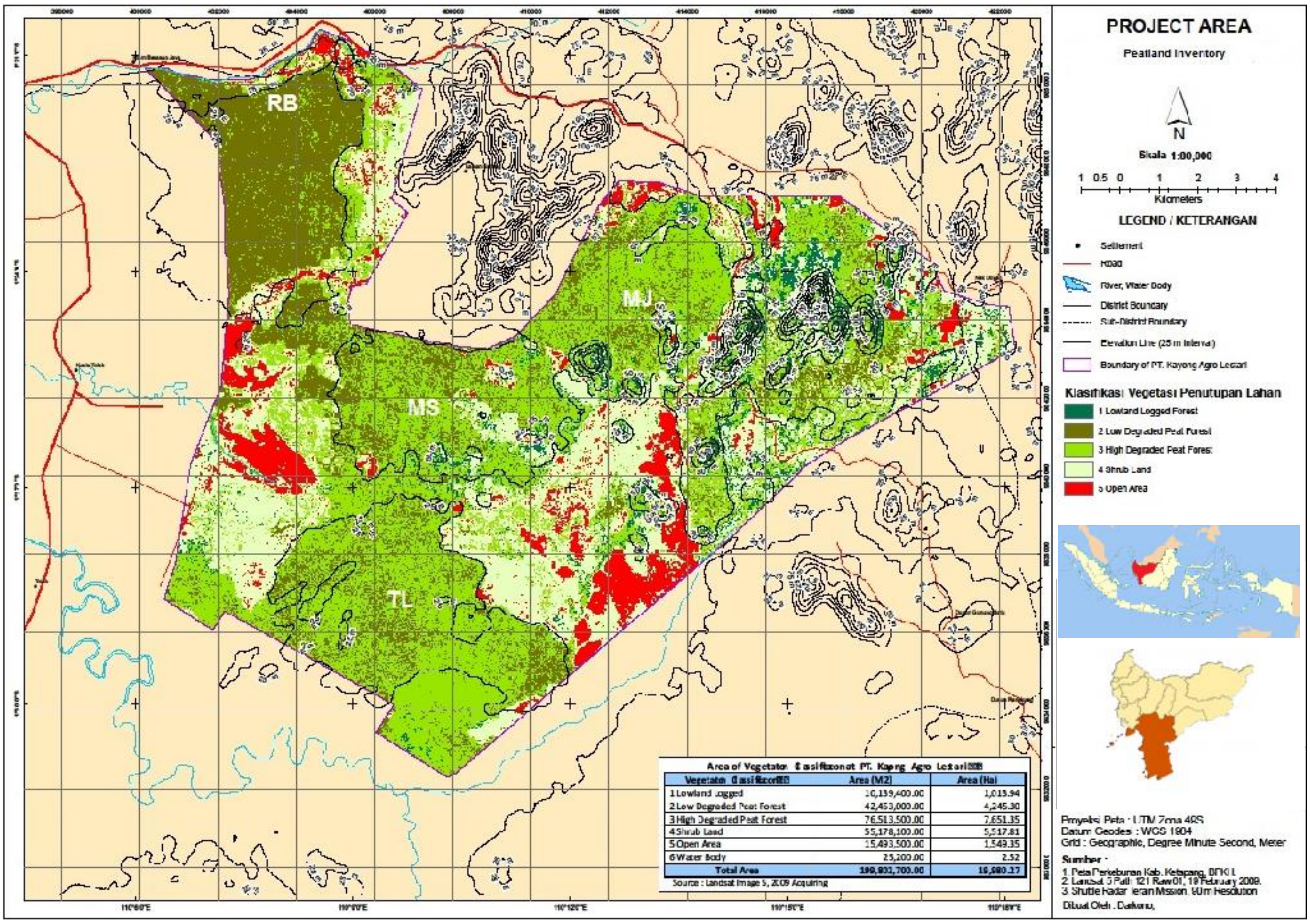


**Figure 1.** Study area map in Riam Berasap (RB) and Tulak (TL) of Ketapang, West Kalimantan, Indonesia

**Figure 2.** Low-impacted logging (A) and wood transportation using 'sepeda' (B) and 'gerobak' (C) on Ketapang, West Kalimantan peatland forest

**Figure 3.**A-B.Forest tree identification and measurement in peatland of Ketapang, West Kalimantan, Indonesia

**Figure 4.**Low (A), intermediate (B), and high (C) degradad peatland forest on Ketapang, West Kalimantan, Indonesia

Within each land cover stratification (low, intermediate, and high degraded forest), concurrently with carbon stock survey team works (Astiani et al. 2016, data not showed), we purposively measured 9-12 plots of a 20m x 100m size all tree species diameter >5cm. In each plot we measured: tree diameter >20cm within 20m x 100m area and tree diameter >5cm>20cm within 5m x 40m nested plot. Throughout each plot, we measured tree diameters, tree heights, and identified tree species local and scientific names. Some species found which not well identified in the field were made herbarium and brought to LIPI and other labs to have species identified.

**Data analysis**

Throughout the estimation of species structure and composition, data are presented as mean and standard error (SE) in selected intervals unless otherwise noted. Analysis of variance ANOVA was used and then Pairwise comparisons (Tukey Procedures) was tested among peatland degradation levels (low, intermediate, high degraded forest) in term of basal area, tree density etc.

## RESULTS AND DISCUSSION

### Forest stratification description

In the entire forest area of peatland in Riam Berasap, 108 species from 39 families were found. The land cover stratification was Low, Intermediate, and Low Degraded Peat Forest. Each land cover and canopy opening of forest stratification could be described as follows and visualized in Figure 4, and the peatland forest structure is drawn in Figure 5 and 6.

*Low Degraded Peat Forest* (LDPF). This type of forest is covered by low impacted logged-over peat forest, mainly old secondary peat forest that had occurred at least more than 10 year ago. Peat forest is in good succession, indicated by sufficient level of young trees and they formed 'J-shaped' as an indicator of balance uneven structure of trees. There are 80 tree species listed that compose this forest type. In general, for the whole area forest cover are dominated by Jungkang (*Pouteria malaccensis*), Nyatoh daun lebar (*Palaquium coclearifoium*), Nyatoh punjok (*Palaquium pseudorostratum*), Ubah, Perepat (*Sonneratia alba*), and Nyatoh beras (*Palaquium ridleyii*). Low Degraded Peat Forest dominated by trees (diameter >20 cm) and poles (diameter 5-<20cm) with stem density 258.9 ± 30.6 trees/ha and 340.7 ± 62.9 tree/ha consecutively. Canopy gaps assessment resulted they ranged from close to medium opened canopy, and showed very good succession of younger and smaller trees growth. Mean tree basal area was 22.6 ± 2.0 $m^2$/ha (N=14)

*Intermediate Degraded Peat Forest* (IDPF). This forest mainly secondary peat forest, that recently (less than 5-6 year ago) disturbed by logging. Dominant tree species in intermediate was similar to low degraded one such as mentioned above, yet they had less stem density with opened to rather opened canopy. The stem densities for tree diameter >20 cm and 5-<20cm were 199.5 ± 23.1 and 358.0 ± 21.3 consecutively. The trees diameter >20 cm quantity is approximately four fifth of the LDPF, yet the stem density of smaller trees is not different, only a bit higher than LDPF. The basal area was also less than LDPF (19.6 ± 2.3 $m^2$/ha (N = 11). The species composition was altered their dominance which prominent species registered such as Jonger (*Ploiarium alternifolium*), Kelentit Nyamuk (*Mangifera swintonioides*), Kumpang perawas (*Gymnacranthera contracta*), Nyatoh Banir (*Palaquium ridleyii*), Unang-unang (*Polyathia sumatrana*) and Leban Paya (*Porterandia anisophyllea*).

*High Degraded Peat Forest* (HDPF). These forests were mainly high degraded secondary peat forest that recently open or burned scatter and found interspaced among the other two canopy cover conditions. Vegetation was dominated by a few tree, pole, and saplings level tree growth and shrubs ferns, grasses were found scattered. The stem density was 130.8 ± ± 22.1 and 372.9 ±46.2 for tree diameter >20 cm and 5-<20cm. Its mean basal area was 13.2 ± 2.0 $m^2$/ha (N = 7). Some prominent species found were Jungkang (*Pouteria malaccensis*), Leban Tikus (*Vitex secundiflora*), Mentepis (*Calophylum inophyllum*), Keminting hutan (*Polyalthia glauca*), and Bintik (*Elaeocarpus graffithii*).

When we compared tree density among forest condition, it shown that tree diameter >20cm were significantly reduced their density in high degraded forest compared to low degraded one, while intermediate stage was a transition state between the low and high degraded forest. Smaller trees were relatively similar density (Figure 5).Difference in stand density affected their basal areas when compared amongst them. Reduction in basal area on high degradation forest reached 41,3% for tree diameter >20cm, yet increased ~33% for tree diameter 5-<20cm (Figure 6).

### Tree species diversity among forest degradation levels

Resultsshowed that forest degradation had significant impacts on tree diversity in tropical peatland of Riam Berasap. Higher level of forest degradation reduced tree diversity variously and significantly influenced the existing peatland forest. For larger trees (diameter >20cm), there were found82, 72, and 48 tree species in low, intermediate, and high forest degradation respectively, while in smaller trees, in similar order of degradation,there were 61, 53, and 28 tree species Figure 4. demonstrated that high degraded peatland forest decreased tree species diversity of 14% from low to intermediate and 43% from low to high degraded one.

Some species were lost in high degraded forest, and yet some other species emerged, while others survived among the tree degradation levels (Figure 5, Table 1). There were 45 species that found in low degraded forest that were not present in high degraded one. The most prominent species losses were some species of Nyatoh i.e. Nyatoh beras daun lebar (*Palaquium coclearifoium*), Nyatoh punyok (*P. pseudorostratum*), Nyatoh Babi (*P. xanthochynum*), Nyatoh Beras (*P. ridleyii*), Ubah (*Syzigium spicata*), Bintangur (*Calophyllum hosei* Ridley), Kayu Cin (*Nageia wallichiana* (Presl.) O.K.) and other important species where found abundant in low degraded peatland. On the other hand, 10 species were found in high degraded forest such as Mentepis (*Calophylum inophyllum*), Mengkasai (*Cyathocalyx biovulatus*), Ilas (*Neoscortechinia kingii* King), Gelam tikus (*Eugenia cerina* Endl.) were not available in low degraded one.

Viewing from forest ecology side, Shannon-Winner Index (Diversity Index) of trees among the three degradation levels were consider high (3.63, 3.32, and 3.21) consecutively for low, intermediate and high degraded peatland forest. It is indicated that among the three forest coverage levels they were all high in tree species diversity. Tree species in each forest condition has relatively diverse in tree abundance especially when low and high degraded forest compared, that shown from their Eveness Index which were 0.63 and 0.43.When analyzing their Similarity Index, their species composition were relatively shifted. The value were 41.5%, 34.3%, and 30.1%respectively when contrasting low vs intermediate, low vs high, and intermediate vs high degraded peatland forest. Those values described that between the 2 forest condition they have <50% tree species in common.

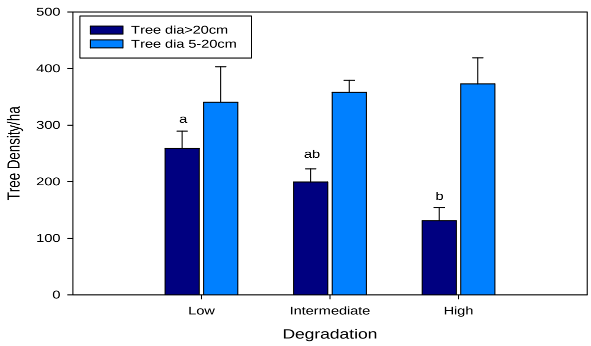


**Figure 5.** Peatland forest tree density among degradation levels

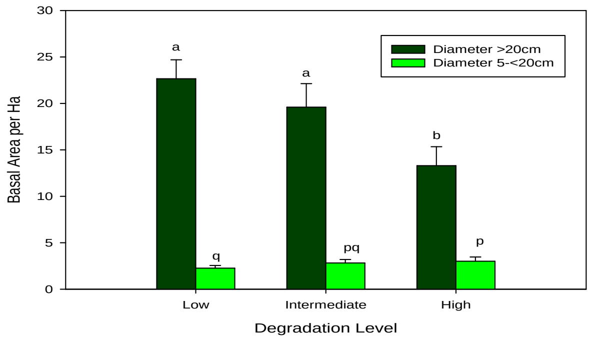


**Figure 6.** Tree basal area at various level of peatland forest degradation

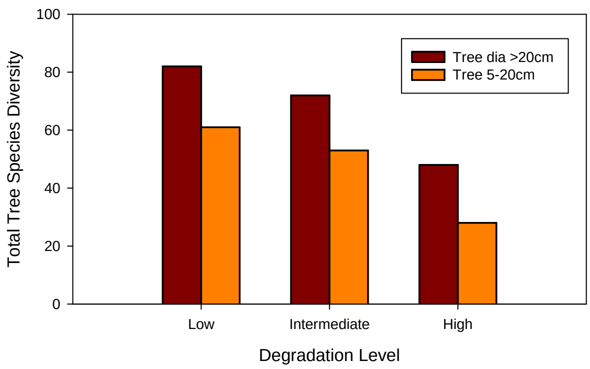


**Figure 7.** Total tree species diversity found among degradation level in peatland forest of Riam Berasap, Ketapang, West Kalimantan, Indonesia

## Discussion

Simply, forest ecosystem classification is based on their type of habitat (i.e. tropical peatland forest is forest that is growing on peatland).However, forest ecosystem itself contribute to abundant and complicated roles in nature. There are variety of ecosystem function derived from tropical forest such as their roles in biogeochemical cycles, biological diversity, carbon sequester, improving welfare for people, opportunities on research, recreation and other ecosystem services (Putz and Redford 2010) and forest type description solely will mislead those ecosystem function.

Tropical peatland forest is one of vegetation ecosystem type which maintain enormous roles in their landscapes. Recent condition and on going pressure on this ecosystem type could have devastating impacts on biodiversity of forest. The problems that are fundamental for maintaining and monitoring biodiversity is not yet appropriate at present even though several technique has been established to monitor forest such as land cover mapping and monitoring, either on local, regional, and continental scale (Eva et al 2010; Margono et al 2012). Our concerns on peatland forest conservation in West Kalimantan led us to study the impact of forest degradation and revealed the facts of peatland tree biodiversity influenced by the anthropological degradation. These results acknowledge and clarify exact impacts of forest degradation (even though this area was practiced by low impact logging before) to the future peatland forest structure and species composition.

Forest structure is related to physical arrangement, intermixing size and composition distribution and other components in the forest that are related to ecological function and processes that also encompasses species composition and basal area (McElhinney et al. 2005; Husch et al. 2002; Hansen et al. 2001). Results show that forest degradation altered forest tree density and forest basal area per hectare although this forest has been abandoned for about 10 years. The density of larger trees was decreased, while younger/smaller trees were increased when the degradation level rose. This result supported our previous finding in peatland forest of Kubu Raya West Kalimantan (Astiani 2014). Reducing larger trees in higher level of degradation, gave more opportunity to younger trees due to optimal gap size produced (Curran et al. 1999). Prescott et al. (2003) and Denslow et al. 1998 mentioned that large gap size enhance N mineralization and phosphorus availability that elevate their concentration available N and P for enhancing tree growth. Increasing canopy gap size has been shown to impart greater microclimate change on in the forest floor (Asbjornsen et al. 2004; Proe et al. 2001; Barton et al. 1989).These results imply that in tropical peatlands, forest degradation and land cover change-with corresponding alterations of soil microclimate (e.g., temperature, $CO_2$, light, humidity)-will influence forest growth and dynamics.

The shifts also occurred on species composition. Species diversity was reduced when forest degradation increased. Moreover, some new species found their new sites in highly degraded forest. Although all those forest cover levels have relatively high in diversity, the species diversity shiftings are circumstances which need to be considered. The alteration of tree species composition could permanently cause the extinction of several important tree species along the peatland landscape. This post-logging dynamic in high degraded forest diminished more than one third species previously present in low degraded one. Most of species lost were high economic and conservation value timber/wood when logged, leaving less valuable tree species in high degraded forest. In term of tree species conservation, a lot of important tree species in tropical peatland (e.g., *Gonystylus bancanus, Shorea belangeran, Shorea teijsmanniana, Pouteria* spp., *Palaquium* spp. etc.) could be endangered when forest degradation continued.

**Table 1.** Species composition and tree density among forest degradation levels in peatland of Ketapang, West Kalimantan, Indonesia

| Species | Local name | Tree density/Ha | | |
|---|---|---|---|---|
| | | Low | Intermediate | High |
| *Actinodaphne sphaerocarpa* (Bl.) Nees. | MedangAsam | 0.6 | 1 | 0 |
| *Adenanthera pavonina*Lam. | Empahong | 0 | 1 | 0 |
| *Aglaia rubiginosa* Blume. | Parak | 0.6 | 1 | 0 |
| *Alangium longiflorum* Merr. | Mengkapas | 11.1 | 0 | 1.7 |
| *Alangium* sp. | Mengkapas | 0.6 | 0 | 0.8 |
| *Alseodaphne coreasea* Nees | Medang Pasir | 0 | 0 | 0.8 |
| *Alstonia spatulata* Blume | Pelaik Pipit | 2.8 | 0 | 0 |
| *Blumeodendron takbrai* (Blume) Kurz | Mengkajang | 0.6 | 0 | 0 |
| *Buchaniana arborescens* Blume | Mate udang | 2.8 | 0 | 0 |
| *Calophyllum hosei* Ridley | Bintangur | 5.6 | 4.5 | 0 |
| *Calophylum inophyllum* Lam. | Mentepis | 0 | 2.5 | 4.2 |
| *Calophylum schlerophyllum* Lam. | Bintangor | 0.6 | 0 | 0 |
| *Camnosperma squamatum* Ridl. | Terentang Putih | 2.2 | 0 | 0 |
| *Cantleya corniculata* (Becc) Howard. | Bedaru | 8.3 | 4 | 0.8 |
| *Choriophyllum malayanum* Bth.. | Ubah Merah | 0 | 0.5 | 0.8 |
| *Cratoxylum glaucum* Korth. | Gerunggang | 2.2 | 1 | 0.8 |
| *Cyathocalyx biovulatus* Boerl | Mengkasai | 0 | 0 | 2.5 |
| *Dactylocladus stenotachys* Oliv. | Mentibu | 8.3 | 0.5 | 0.8 |
| *Dillenia pulchella* (Jack) Gilg. | Simpur Laki | 1.1 | 1.5 | 0 |
| *Diospyros bantamensis* Kds.et Val. ex Bakh. | Kayu Malam dl | 0 | 3 | 0 |
| *Diospyros maingayi* (Hiern.) Bakh. | Kayu Malam | 1.1 | 1 | 0 |
| *Dipterocarpus bornensis* Slooten. | Keruing Paya | 0 | 0 | 0.8 |
| *Durio carinatus* (Mast). | Durian Burung | 0.6 | 0 | 1.7 |
| *Dyera costulata* Hook.f. | Jelutung | 3.9 | 1 | 0.8 |
| *Elaeocarpusmastersii* King | Mentanang | 0.6 | 0 | 0 |
| *Elaeocarpus griffithii* A. Gray | Mempening | 1.7 | 1.5 | 0.8 |
| *Elaeocarpus petiolatus* (Jack) Wallich ex Steudel. | Pangal | 2.2 | 2 | 0.8 |
| *Elaeocarpus* sp. | Mencubok | 0 | 1.5 | 0 |
| *Eugenia cerina* Endl | Gelam Tikus | 0 | 1.5 | 0.8 |
| *Eugenia spicata* Lam. | Ubah | 11.1 | 1 | 0 |
| *Eugenia* sp. | Kelempit | 0 | 0 | 0.8 |
| *Ganua mottleyana* Pierre ex Dubard | Ketiau | 1.7 | 0.5 | 0 |
| *Garcinia cf. bancana* Miq. | Manggis Hutan | 0 | 0.5 | 0.8 |
| *Garcinia parvifolia* (Miq.) Miq. | Asam Kandis | 1.7 | 2.5 | 0 |
| *Gluta wallichii* (Hook.f.) Ding Hou | Meransing | 0 | 1 | 0 |
| *Gonystylus bancanus* (Miq.) Kurz | Ramin | 3.9 | 0.5 | 0.8 |
| *Gonystylus hankenbergii* Diels. | Ramin Buaya | 0.6 | 0 | 0 |
| *Gymnacranthera contracta* Warb. | Kumpang perawe | 0 | 9 | 0 |
| *Gymnacranthera* sp. | Kumpang | 2.8 | 0.5 | 3.3 |
| *Ilex cymosa* Blume | Mensire | 0 | 1 | 0 |
| *Ilex cf hypoglauca* (Mig.) Loes. | Rawe Aek | 1.7 | 0 | 0 |
| *Knema cinerea* Warb. | Mendarahan1 | 1.1 | 0 | 0 |
| *Knema kunleri* Warb. | Mendarahan 2 | 1.1 | 0 | 0 |
| *Koompasia malaccensis* (Maingay) Benth. | Kempas | 4.4 | 0.5 | 3.3 |
| *Litsea elliptica* Blume. | Medang sp.1 | 0.6 | 0 | 0 |
| *Litsea gracilipes* Hook.f. | Medang Lendir | 0.6 | 0 | 0 |
| *Litsea grandis* 1 (Wall ex Nees) Hook.f. | Medang Kelincir | 0.6 | 0 | 0 |
| *Litsea nidularis* Gamble | Medang Keladi | 2.2 | 0 | 0 |
| *Litsea resinosa* Blume | Medang Perawas | 0.6 | 0 | 0 |
| *Litsea rufo-fusca* Kosterm. | Medang sp2 | 0 | 0 | 0.8 |
| *Litsea* sp. | Medang kunyit | 1.1 | 0 | 0 |
| *Litsea turfosa* Kosterm. | Medang mali | 0 | 0.5 | 0 |
| *Macaranga caladiifolia* Beccari | Garung | 0 | 1 | 0 |
| *Macaranga pruinosa* (Miq.) Muell. Arg. | Mahang | 0 | 1 | 0 |
| *Madhuca mottleyana* (de Vr.) Baeh. | Nyatoh Ketiau | 2.2 | 0 | 2.5 |
| *Magnolia bintulensis* (A. Agostini) Noot.) | Medang limau | 2.2 | 0.5 | 0 |
| *Magnolia* sp. | Medang Kuning | 0.6 | 0 | 0.8 |
| *Mangifera longipetiolata* King. | Rerawe Babi | 0 | 5 | 0 |
| *Mangifera swintonioides* Kosterm. | Kelentit Nyamuk | 3.3 | 9.5 | 0 |
| *Mezzetia leptopada* Hk. f. & Th. | Keminting d kecil | 1.1 | 0 | 0 |
| *Mezzetia parviflora* Becc. | Mempisang | 1.7 | 1 | 1.7 |
| *Mezzetia umbelata* Becc. | Keminting d besar | 1.1 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| *Nageia wallichiana* (Presl.) O.K. | Kayu Cin | 4.4 | 0 | 0 |
| *Neoscortechinia kingii* King | Ilas | 0 | 0.5 | 1.7 |
| *Nephelium maingayi* Hiern | Rambutan Hutan | 2.2 | 0.5 | 0 |
| *Notaphoebe umbeliflura* Blume | Medang Bulu | 0 | 0.5 | 0 |
| *Palaquium coclearifoium* Boerl. | Nyatoh dl | 23.9 | 1.5 | 0 |
| *Palaquium lanceolata* Blanco | Nyatoh dk | 0 | 0.5 | 0 |
| *Palaquium leicocarpum* Boerl. | Nyatoh Cermai | 0.6 | 0 | 0 |
| *Palaquium pseudorostratum* H.J.Lam | Nyatoh Punjok | 22.8 | 1 | 0 |
| *Palaquium ridleyi* King & Gamble | Nyatoh Beras /Banir | 7.2 | 8.5 | 1.6 |
| *Palaquium ridleyi* King & Gamble | Nyatoh Beras | 14.4 | 1 | 0 |
| *Palaquium xanthochynum* Pierre. | Nyatoh Babi | 11.7 | 4.5 | 0 |
| *Parkia singularis* Miq. subsp. *borneensis* | Petai Hutan | 1.1 | 0.5 | 1.7 |
| *Ploiarium alternatifolium* (Vahl) Melch. | Jonger | 2.8 | 46 | 0 |
| *Polyalthia glauca* (Hassk.) Boerl. | Keminting Hutan | 6.1 | 3 | 3.3 |
| *Polyathia sumatrana* (Miq.) Kurz. | Unang-unang | 1.7 | 7.5 | 0 |
| *Pometia pinnata* J.R. & G. Forst. | Kasai | 0.6 | 1.5 | 0 |
| *Porterandiaanisophylla* (Jack ex Roxb.) Ridl | Leban Paya | 5.6 | 6 | 2.5 |
| *Pouteria malaccensis* (Clarke) Baehni | Nyatoh Jungkang | 40.6 | 0.5 | 22.5 |
| *Pouteria obovata* (R.Br.) Baehni | Nyatoh duduk | 3.4 | 0.5 | 0 |
| *Pternandra galeata* (Korth.) Ridl. | Meransik | 2.8 | 0 | 0.8 |
| *Santiria laevigata* Blume forma *glabrifolia* H.J.Lam | Asam Rawe | 0 | 0 | 0.8 |
| *Shorea belangeran* (Korth.) Burck. | Belangir | 0.6 | 0 | 0 |
| *Shorea parvifolia* Dyer. | Meranti | 0 | 1.5 | 0 |
| *Shorea parvistipulata* Heim. | Meranti Rawa | 0.6 | 0 | 1.7 |
| *Shorea teijsmanniana* Dyer ex Brandis | Meranti Batu | 0 | 1 | 0 |
| *Shorea uliginosa*Foxw | Meranti Bunga | 0 | 3 | 0 |
| *Sindora leiocarpa* Backer ex K. Heyne | Sindur | 1.1 | 0 | 0 |
| *Sonneratia alba* Seem. | Perepat | 21.1 | 0.5 | 0.8 |
| *Stemonurus scorpioides* Becc. | Mempasir dl | 0.6 | 1 | 0.8 |
| *Stemonurus secundiflorus* Blume | Mempasir dk | 1.7 | 0.5 | 1.7 |
| *Sterculia lychnophora* Hance | Semangkok | 3.9 | 2 | 0 |
| *Syzygium havilandii* (Merr.) Merr. & L.M.Perry | Ubah Bentan | 3.9 | 0.5 | 0 |
| *Syzygium lineatum* (DC.) Merr.& L.M. Perry | Ubah Jangkar | 0.6 | 0 | 0 |
| *Syzygium* sp. | Ubah Bunga | 0 | 4 | 0 |
| *Syzygium zollingerianum* (Miq.) Ams. | Ubah Jambu | 0.6 | 0 | 0.8 |
| *Tabernaemontana macrocarpa* Jack | Bintik | 1.7 | 2 | 3.3 |
| *Tetractomia tetrandra* Craib. | Ubah Putih | 5 | 1.5 | 0.8 |
| *Tetramerista glabra* Miq. | Punak | 7.2 | 0.5 | 0.8 |
| *Teysmaniadendron*sp. | Nyatoh sp.1 | 6.1 | 5.5 | 1.7 |
| *Tristaniopsis cf merguensis* (Griff.) Peter G.Wilson & J.T.Waterh. | Pelawan | 1.1 | 0 | 1.7 |
| *Vatica mangapachoi* Blanko | Resak | 0.6 | 0 | 0.8 |
| *Vitex secundiflora*Hallier f. | Leban Tikus | 5 | 0.5 | 8.3 |
| *Xanthophyllum ellpticum* Korth. ex Miq. | Menjalin | 1.1 | 0.5 | 0 |
| *Xylopia coryfolia* (Griseb.) King & Robins. | Angin-angin | 0 | 0.5 | 0 |
| *Xylopia fusca*Maingay ex Hook. f. & Thomson | Bahang | 0 | 1 | 0 |

Furthermore, there are numerous hydrological and ecological functions of tropical peatlands ranging from regulation of water flow to providing refuge for endangered animal species (Rieley and Page 2005). The increasing scarcity of available 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. Escalating rates of logging, drainage, fires, conversion to plantations and expansion of small-holder dominated mosaic landscape have occurred since the 1980sand continued until recent time. These activities disturb ecosystem functions invariably, both directly because of altering forest dynamics, reduction of living biomass and acceleration in peat oxidation (Hooijer et al. 2006, 2010; Couwenberg et al. 2010) and indirectly by making the ecosystems more vulnerable to yearly fire activity (Siegert et al. 2001; Page et al. 2002). The species composition and abundance shifting due to forest degradation should be considered on peatland forest management to hinder permanent species loss.

## ACKNOWLEDGEMENTS

I thanks to Flora Fauna International (FFI)-Indonesian Programme for opportunity in studying our valuable and unique forest ecosystem of peatland forests in Ketapang, West Kalimantan, especially to Andjar Rafiastanto, Darkono and all FFI staffs whose being so supportive and helpful. I would like to thank to people of Desa Riam Berasap, Desa Manjau and especially Desa Sungai Putri supports on me conducting this study. Thank you to PT. Kayong Agro Lestari, Ketapang, West Kalimantan for their supports and facilitation, these companies collaborated with FFI allow me to conduct part of this field works within their concession. I am grateful for assistance in the field and laboratory works to Mujiman, M. Hatta, Edy Nurdiansyah, Sri (Cei) Yuliani, and Hanisah who always relentlessly supporting my field works in many incredible ways and endless helps.

## REFERENCES

Asbjornsen H, Ashton MS, Vogt DJ, Palacios S. 2004.Effects of habitat fragmentation on the buffering capacity of edge environments in a seasonally dry tropical oak forest ecosystem in Oaxaca Mexico. Agric Ecosys Environ103: 481-495.

Achard F, Eva HD, Stibig HJ. 2002. Determination of deforestation rate of world's humid tropical forest. Science 297: 999-1002.

Astiani D. 2012. Carbon assessment in PT Kayong Agro Lestari (KAL) Kabupaten Ketapang, West Kalimantan. Assessment Report. Flora Fauna International-Indonesia Programme. Jakarta

Astiani D. 2014.Bornean Peatlands: Forest Dynamics, Land Use and Carbon Flux. [Ph.D. Dissertation]. Yale University, New Haven, USA.

Barton AM, Fetcher N, Redheads. 1989. The relationship between treefall gap size and light flux in Neotropical rain forest in Costa Rica. J Trop Ecol 5: 437-439.

Cardilee J, Folet JA. 2001. Agricultural landuse change in Brazilian Amazon between 1980 and 1995: evidence from integrated satellite and census data. Remote Sens Environ 87: 551-562.

Carlson KM, Curran LM, Ratnasari D. Pittman AM, Soares-Filho BS, Asner GP, Trigg SN, Gaveau DA, Lawrence D, Rodrigues HO. 2012. Committed carbon emissions, deforestation, and community land conversion from oilpalm plantation expansion in West Kalimantan, Indonesia. Proc Natl Acad Sci USA 109: 7559-7564.

Carlson KM, Curran LM, Asner GP, Pittman AM, Trigg SN, Adeney JM. 2013. Carbon emissions from forest conversion by Kalimantan oil palm plantations. Nat Clim Ch 3 (3): 283-287.

Celine E, Philippe M, Astrid V, Catherine B, Musampa C, Pierre D. 2013. National forest cover change in Congo Basin: deforestation, reforestation, degradation and regeneration for the years 1990, 2000 and 2005.Glob Ch Biol 19:1173-1187.

Curran LM, Caniago I, Paoli GD, Astiani D, Kusneti M, Leighton M, Nirarita E, Haeruman H. 1999. Impact of El Niño and logging canopy tree recruitment in Borneo. Science 286:2184-2188.

Couwenberg J, Dommain R, Joosten H. 2010.Greenhouse gas fluxes from tropical peatland in South-East Asia. Glob Ch Biol 16: 1715-1732.

Curran LM, Caniago I, Paoli GD, Astiani D, Kusneti M, Leighton M, Nirarita E, Haeruman H. 1999. Impact of El Niño and logging on canopy tree recruitment in Borneo. Science 286: 2184-2188.

Denslow J, Ellison AM, Sanford SE.1998.Tree fall gap size effects on above and below ground processes on tropical wet forest. J Ecol 86: 597-609.

Dirzo R, Raven PH. 2003. Global state of biodiversity and loss. Ann Rev Environ Resour 28: 137-167.

Eva H, Carboni S, Achard F, Stach N, Durieux L, Faure J-F, Mollicone D. 2010. Monitoring forest areas from continental to territorial levels using a sample of medium spatial resolution satellite imagery. ISPRSJ Photogram Remote Sens 65: 191-197.

FAO [Food and Agricultural Organization]. 2010. Global forest resources assessment 2010 country report. Indonesia Forest Resources Assessment (FRA) 2010/095, UNFAO, Rome.

Foley JA, Asner GP, Costa MH, Coe MT, De Fries R, Gibbs HK, Howard EA, Olson S, Patz J, Ramankutty N, Snyder P. 2007. Forest Degradation and loss of ecosystem goods and services in the Amazon Basin. Ecol Environ 5 (1): 25-32.

Grainger A. 1993. Controlling Tropical Deforestation. Earthscan, London.

Hooijer A, Silvius M, Wösten H, Page SE. 2006. PEAT-$CO_2$, Assessment of $CO_2$ emissions from drained peatlands in SE Asia. Delft Hydraulics Rep Q 3943.

Hoojiers A, Page S, Canadell G, Silvius M, Kwadijk J, Wosten H, Jauhiainen J. 2010. Current and future $CO_2$ emissions from drained peatlands in Southeast Asia. Biogeosciences 7: 1505-1514.

IPCC [Intergovernmental Panel on Climate Change]. 2011. Summary for Policymakers. In:Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P, Kadner S, Zwickel T, Eickemeier P, Hansen G, Schlomer S, von Stechow C (eds). IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Hansen AJ, Neilson RP, Dale VH, Flather CH, Iverson LR, Currie DJ, Shafer S, Cook R, Bartlein PJ. 2001. Global change in forest: Response of species, communities and biomass.Bioscience 51 (9): 765-779.

Husch B, Beer WT, Kershaw AJ. 2002. Forest Mensuration. 4$^{th}$ ed. John Wiley and Sons, London.

Lambin EF.1999. Monitoring forest degradation in tropical region by remote sensing: some methodological issues. Glob Ecol Biogeogr 8: 191-198.

McElhinney C, Gibbons P, Brack C, Bauhas J. 2005. Forest and woodland stand structural complexity: its definition and measurement. For Ecol Manag 218 (3): 1-24

Margono BA, Turubanova S, Zhuravleva, Potapov P, Tyukavina A, Baccuni A, Goetz S, Hansen MS. 2012. Mapping and monitoring deforestation andforest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010. Environ Res Lett 7 (034010): 1-16.

Ministry of Forestry of Indonesia. 2011.Land Cover Recalculation of Indonesia in 2009/2010. Planning Agency, Department of Forestry Indonesia, Jakarta. [Indonesian]

Miettinen J, Shi C, Liew SC. 2011. Influence of peatland and land cover distribution on fire regimes in insular Southeast Asia. Reg Environ Ch 11: 191-201.

Nepstad DC, Verissimo A, Alenca A. 1999. Large scale impoverishment of Amazonian forest by logging and fire. Nature 398: 505-508.

Page SE, Siegert F, Rieley JO, Boehm HDV, Jaya A, Limin S.2002. The amount of carbon released from peat and forest fires in Indonesia in 1997. Nature 420: 61-65.

Prescott CE, Hope GD, Blevin LL. 2003. Effect of gap size on litter decomposition and soil nitrate concentrations in a high spruce-fir forest. Can J For Res 33: 2210-2220.

Proe MF, Griffiths JH, McKay HM. 2001.Effect of whole tree harvesting on microclimate during establishment of second rotation forestry. Agric For Meteorol 110: 1410-154.

Putz FE, Redford KH. 2010. The importance of defining forest: tropical forest degradation, deforestation, long-term phase shifts, and further transitions. Biotropica 42 (1): 10-20.

Rieley JO, Page SE. 2005.Wise Use of Tropical Peatland: Focus of Southeast Asia, ALTERRA-Wagenigen University and Research Center and the EU INCO-STRAPEAT and RESTORPEAT Partnership, Wageningen.

Siegert F, Rueckee G, Hinrich A, Hoffman AA. 2001. Increase damage from fires in logged forest during droughts cause by El Niño. Nature 414: 437-440.