BIODIVERSITAS
Volume 19, Number 1, January 2018
Pages: 272-278

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190137

Edge effects on biomass, growth, and tree diversity of a degraded peatland in West Kalimantan, Indonesia

DWI ASTIANI[1,4♥], LISA M. CURRAN[2], MUJIMAN[3], DESSY RATNASARI[3], RUSPITA SALIM[3], NELLY LISNAWATY[3]

[1]Faculty of Forestry, Universitas Tanjungpura. Jl. Prof. Hadari Nawawi, Pontianak 78124, West Kalimantan, Indonesia. Tel.: +62-561-765342, 583865, 732500, Fax.: +62-561-765342, ♥email: astiani.dwi@gmail.com
[2]Stanford Wood Institute for the Environment, Stanford University. Stanford, CA 94305, USA
[3]Landscape Livelihood Indonesia (LLI) Institute. Pontianak 78121, West Kalimantan, Indonesia
[4]Consortium of Tropical Peat Sciences, Kalimantan Universities Consortium. C.q. Universitas Tanjungpura. Pontianak 78124, West Kalimantan, Indonesia

Manuscript received: 5 June 2017. Revision accepted: 14 January 2018.

Abstract. *Astiani D, Curran LM, Mujiman, Ratnasari D, Salim R, Lisnawaty N. 2018. Edge effects on biomass, growth, and tree diversity of a degraded peatland in West Kalimantan, Indonesia. Biodiversitas 19: 272-278.* Tropical forested peatlands in Indonesia are threatened by logging and clearing which reduce their ecosystem functions and degrade the environment. Land use change activities disturbed intact forests, resulted in landscape fragmentation. Scattered forest matrices resulted in forest edge areas, which will considerably affect the forest biotic and abiotic conditions, as well as forest tree dynamics within the edge sites. The goal of this study was to investigate the effect of forest edge on perimeter of the forest fragment on the forest biomass stock, growth, tree basal area as well as species composition, richness and abundance in a degraded peatland forest in West Kalimantan. A twelve-ha forest was divided into 35 plots in the interior forest and 13 at the forest edge; each plot was 50 m by 50 m in size based on their abiotic conditions such as light and temperatures. Leaf Area Index (LAI) was measured in each plot of both forest edge and interior sites using Licor-2100. The results indicated that even though the biomass levels maintained relatively moderate to high levels on both sites, forest edge significantly lowered forest biomass by 32%, reduced 23-25% of tree-biomass growth per unit area for both tree diameter of 10-20 cm and >20 cm. There was a shift of tree species composition, 76 species were found on both sites, 24 species were not found in edge site, but present in the interior site and 10 species were found only in edge site. Peatland forest matrix created forest edges that are lowering peatland forest roles in sequestering carbon per unit area and reducing species diversity. Peatland forest restoration should be conducted to reduce forest matrices and to lower the edge effects.

Keywords: Forest edge, forest interior, forest matrix, species abundance, species richness

INTRODUCTION

Tropical forested peatlands provide various ecosystem services, not only to local people and surrounding nature, but also to global population such as biodiversity conservation, hydrology regulation, and carbon storage. However, the ecosystem experiences enormous pressures lately and deserves special attention to prevent its continuous destruction (Celine et al. 2013). Achard et al. (2002) and Miettinen et al. (2011) stated that the deforestation rate of intact forest in Southeast Asian tropical peatlands, concentrated in Sumatera and Kalimantan, Indonesia, was 3.4% per year from 1990-2010. Similarly, tropical forests in Indonesia are also threatened mainly due to anthropogenic activities such as logging and land use and land cover changes (Margono et al. 2012).

Land use and land cover changes cause forest fragmentation which leaves relatively small to large, isolated patches of forest remnants. Forest fragmentation is one of the largest threats to biodiversity in forests (Bierregaard 2001). Forest fragmentation usually creates edge effect, which refers to the changes in population or community structures that occur at the boundary of two habitats. Forest degradation can lead to temporary or permanent destruction, having a negative effect not only on forest vegetation structure, but also on species composition (Astiani 2016); furthermore, the condition can lead to productivity reduction (Grainger 1993; Lambin 1999). Since tropical forests play a major role in regulating global carbon fluxes and stocks, especially in peatland (Maltby and Immirzi 1993; Brown 2002; Hooijer et al. 2010; Astiani and Ripin 2016), even a very small alteration to carbon balance in this biome can have a huge effect on atmospheric greenhouse gasses especially carbon dioxide (Rieley and Page 2005; Hooijer et al. 2006; Uryu et al. 2008; Wood et al. 2012). Globally, however, deforestation and forest degradation are threatening forest's function in CO_2 sequestration (Jaenicke et al. 2008; Saatchi et al. 2011), as well as degrading peatland forest role in inputting water and nutrient to soil (Astiani 2017a). Moreover, deforestation and forest degradation account for approximately 12% of global Greenhouse Gas (GHG) emission (Van Der Werf et al. 2009).

Forest edges are presumed to have deleterious impacts on the trees that remain in the adjacent forest. Previous studies mentioned that they cause forest structure damage (Laurance et al. 1999), and lead to degradation on forest fragments (Gascon et al. 2000). To improve the knowledge on the consequences on forest edge in West Kalimantan peatland forest, the objective of this study was to investigate the effects of forest edge on biomass, growth, mortality and tree diversity of peatland forest in West Kalimantan, Indonesia.

MATERIALS AND METHODS

Site selection and description

The study was conducted in previously logged peatland forests with an ombrotrophic, coastal type peatland in Kubu Raya District, West Kalimantan Province, Indonesia. The research site was located at 0^{o}13' S and 109^{o}26' E, ca 4 m asl. Average temperature was 26.5±0.5 ^{o}C, with minimum and maximum temperature of 22.6 ^{o}C to 32.2 ^{o}C. Mean annual rainfall was 3,218 ± 530 mm (mean ± s.d. rainfall data 2000-2015, West Kalimantan, Supadio Station) without dry months (<100 mm rainfall) per year, even during the onset of the El Niño Southern Oscillation (ENSO).

The study site was selected based on intensive survey and satellite image searching (Landsat ETM+, 30m resolution) that showed unfragmented forest block representing degraded peatland forest in the area. The dominant species in this forest site were *Litsea gracilipes* (Lauraceae), *Pometia pinnata* (Sapindaceae), *Litsea resinosa* (Lauraceae), *Tetramerista glabra* (Tetrameristaceae), *Elaeocarpus griffithii* (Elaeocarpaceae), *Litsea nidularis* (Lauraceae), *Shorea uliginosa* (Dipterocarpaceae) and *Neonauclea excelsa* (Rubiaceae).Throughout the 12-ha area, peat depth was measured and sampled using Russian Peat Corer (Aquatic Research Instrument) coupled with Garmin eTrek GPS readings, and then peat depth distributions were mapped. At this focal site, peat depth ranged from 2.6 m to 5.4 m. Leaf Area Index (LAI) was measured within each plot of interior and edge sites using Licor-2100.

Sampling approaches for collecting data

Biomass and growth assessment

In the previous studies (Astiani 2014), forest tree population was measured within the 12 ha forest block. This area was selectively logged (non-mechanized). Stumps inventory available provided an estimation of 12 trees per ha (> 30 cm DBH), either removed or lost during felling over the site. Local villagers reported that they felled many species of tree, mostly *Shorea* spp. (Dipterocarpaceae) and *Gonystylus* spp. (Thymeleaceae) in 2002-2004 for local construction. In 2011, the remaining Dipterocarpaceae trees comprised 6.8% of the understorey (<10 cm DBH) and 3% of canopy trees (≥10 cm DBH). Mean stem density and tree basal area (>10 cm DBH) yielded 458 trees per ha and 9.73 m^2 per ha and included at least 104 tree species within 31 families whereas seedling (diameter <5 cm) and sapling (5-10 cm DBH) inventory recorded 25,390 ± 1,433 seedlings per ha and 1,113 ± 44.8 saplings per ha (Astiani et al. 2017b).

Based on overlaying Landover Map 2010 and SRTM Spectra with 90 m Resolution, and field vegetation and canopy closure survey, this area was classified into slightly, moderately and highly degraded forest, then the 3 categories were divided into two site conditions, i.e., forest edge and interior. Based on the microclimates condition, the forest edge was classified at approximately 50 m outer layer of the forest fragments. For tree measurement, 13 50 m x 50 m plots were established surrounding the forest fragment to represent forest edge, and 25 50 m x 50 m plots were established within the forest interior site.

Within each plot across both sites (edge and interior) in the study area, tree stems with >10 cm DBH were mapped, tagged, identified to species or at least genus and monitored for growth and mortality for 6 consecutive years. Stems (<10 cm DBH) were measured with a caliper and given a permanent red paint mark at the point of measurement. All stems with >10 cm DBH were fitted with steel dendrometer bands, following Paoli et al. (2008). Dendrometer bands were placed at 1.3 m above the ground or 20 cm above the buttresses and other bole irregularities. The red paint was renewed every six months to prevent visual loss if dendrometer bands rot or were lost. Each tree diameter and biomass growth were measured annually.

Following Astiani (2014) and Paoli and Curran (2007), in this study, we used equation to estimate above-ground biomass produced by Chave et al. (2005) for tropical moist forest that incorporates specific wood densities in the equation. Above-ground net tree biomass was defined as the cumulative growth of all trees that survived through each sampling interval (10-20; and >20 cm DBH following Clark et al. (2001) and Paoli and Curran (2007).

Tree species identification

All tree species were identified and registered. Several approaches were used for identifying tree species in the field, such as bringing species identification key to the field along with some local tree experts and taking herbarium samples. To confirm the species identification, the unknown/unidentified herbarium samples were sent to Indonesian Science Institute (LIPI) botanical collection. The results from LIPI were then brought back to local tree experts to confirm the tree species and to be used for future tree identification.

Data analysis

Throughout this paper, the collected and analyzed data are presented as means and standard errors (SE), while cumulative data are presented as summed data. Trees within a plot were grouped into two size classes (i.e. 10-20 and >20 cm DBH). Biomass and growth of all stems within a size class were summed. Comparisons between edge and interior sites on biomass stocks, growth, basal area, and Leaf Area Index (LAI) were examined using simple t-tests. All analyses were performed using Sigmaplot version 11.2 (Systat Software Inc. 2011).

RESULTS AND DISCUSSION

Edge effects on forest biomass

This study indicated that forest fragmentation reduced forest biomass on the perimeter of forest matrix. Edge site was significantly different from interior site (t-test, t =-2.717; df = 44; P = 0.009). Edge effects decreased the biomass of trees with >10 cm DBH by about 32%. The total of tree means biomass within interior site was 302.1 ± 19.4 ton/ha as opposed to those within edge site which was 206.0 ± 26.5 ton/ha (Fig. 1). The results indicated that in this peatland forest ecosystem, edge effect caused a shift in forest conditions. The impacts of edge effect on forest vegetation could be negative, neutral or positive, depending on the reaction. There were no general patterns on edge effect impact on forest vegetation (Murcia 1995). However, changes in physical environment caused by edge effect might directly affect forest structure which can lead to changes in forest biomass The biomass decreased on edge sites, yet the tree biomass remained relatively high in peatland forest.

The edge effects, however, did not significantly affect tree basal area (Fig.2), yet the basal area was a bit lower in edge sites. The results of basal area quantities showed that the trees space of the area occupied relatively similar area. Further observation revealed that there were fewer trees with larger diameter found within edge site compared to the interior one.

Comparing forest growth within edge and interior sites

Forest growth was affected by edge effects. Besides, the reduction of tree biomass stocks and the ability of forest vegetation (i.e., trees) to store biomass also decreased. Edge effects lowered tree biomass storage by 23-25%, for both trees with diameter of 10-20 cm and >20 cm. This result implied that the opening sites at forest edge caused the forest growth reduction in general, not only for large trees, but also for the small ones (Fig. 3).

LAI readings from both sites were significantly different (Fig. 4). Forest edges caused either more light availability at edge site which promotes tree growth or decrease of growth which killed some light intolerant species. Thus, the forest conditions that affected tree biomass might differ among forest ecosystems. Results of this study indicated that biomass stocks and tree growth were larger in interior than that in edge sites. The results were consistent with those of Astiani (2014) who found that tree growth was significantly affected by tree biomass stocks. The previous study also demonstrated that even though individual tree showed increasing diameter growth, the amount of collective landscape biomass growth (ton/ha) was decreasing because of lower tree density within forest edge sites.

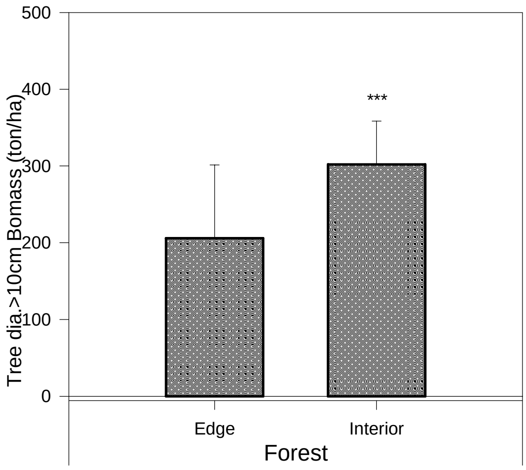

Figure 1. The biomass (ton/ha) of trees with diameter of >10 cm within the edge and interior parts of forested peatlands

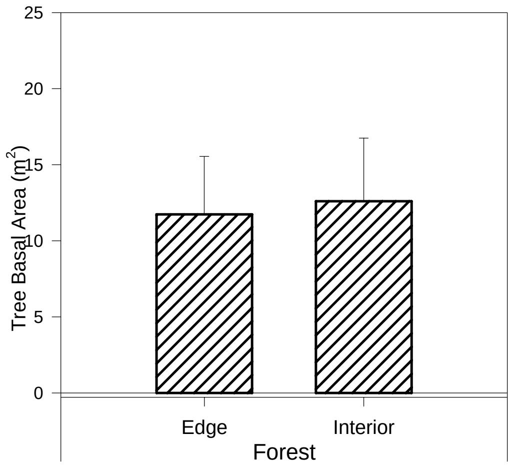

Figure 2. Tree basal area within the edge and interior sites

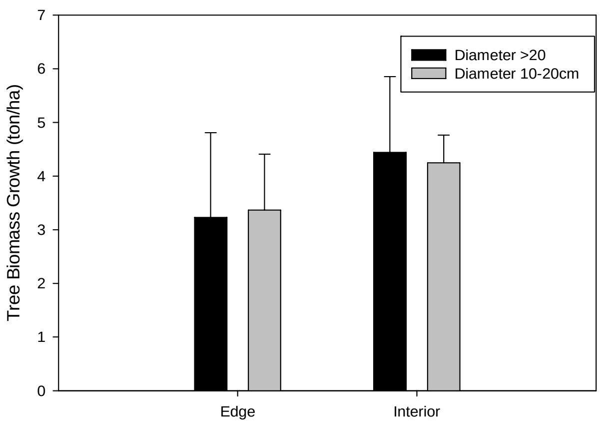

Figure 3. Forest biomass growth within edge vs interior sites

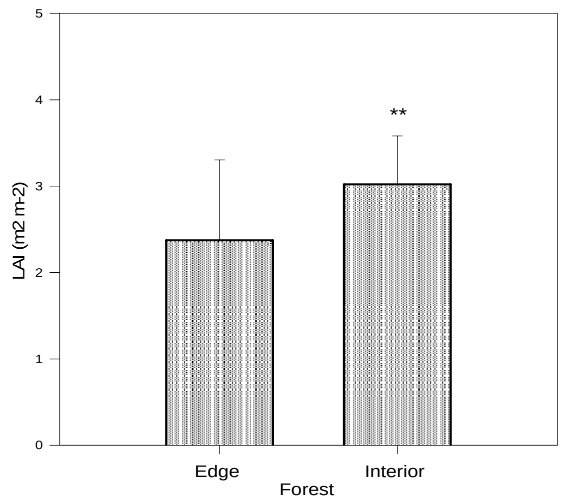

Figure 4. LAI readings on edge vs. interior sites

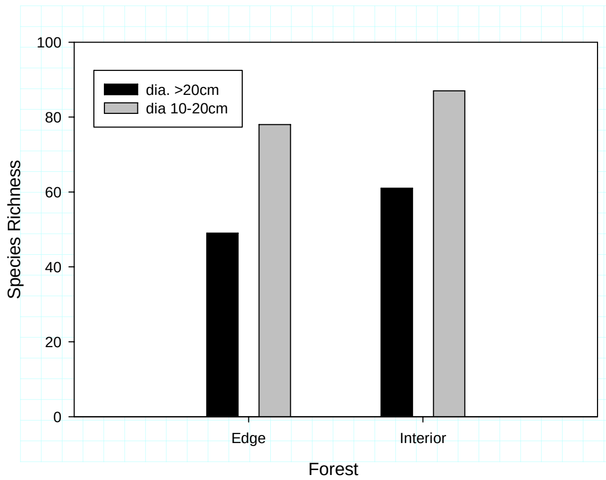

Figure 5. The species richness of trees having diameter of >20 cm and 10-20 cm in the edge and interior sites

Edge effects on species richness

Species richness was altered by forest edge effects in this tropical peatlands. Edge site caused decrease of species richness of forested peatlands. The interface between forested and nonforested peatland ecosystem that usually has limited continuous canopy closure changes the forest tree composition and their species abundant (Harper et al. 2005). This results showed similar trend to those of other studies, such as Sizer and Tenner (1999) in young tropical forest in Amazon forest, temperate (Macquarrie and Lacroix 2003), and Rheault et al. (2003) in boreal areas. Among all edges, there are two similar shift: exchange or flow of energy, material, and organisms, and changes in biotic condition (Cadenasso et al. 2003).

Tree species richness in the edge sites was reduced by 21% and 7%, for trees having diameter of >20 cm and 10-20 cm respectively (Fig. 5). One hundred and four tree species were found in this peatland forest. Tree composition was shifted approximately by 31%, Eighty species were found in both sites, 20 species were not found in the edge site but present in the interior site, and 4 species were found only in the edge site (Table 1.). The dominant tree species that could be lost were, for example, medang lendir (*Litsea gracilipes*), ubah merah sp1 (*Syzygium lineatum*), kayu malam (*Diospyros maingayi*), kempas (*Koompasia malaccensis*), terentang merah (*Gluta wallichii*), and keminting hutan1 (*Mezzetia* sp.*).* Some other species found their new site at forest edge such as tenggayun (*Artocarpus* sp.), buah ular (*unknown*), parak (*Chisocheton patens*), petai belalang (*Archidendron borneense*), and menjalin (*Xanthophyllum ellipticum*).

Further investigation indicated that 52 species had lower abundance in the edge sites, for example, kasai (*Pometia pinnata*), mempening (*Elaeocarpus griffithii*), punak (*Tetramerista glabra*), meranti bunga (*Shorea uliginosa*), medang perawas (*Litsea resinosa*), medang keladi (*Litsea nidularis*), etc.**.** On the other hand, the tree abundance of 24 species was increasing in the edge sites (Table 1).

Edge effects also affected species distribution within the edge sites. It might be because of different levels of tolerance of light among tree species (Murcia 1995). Results of this study showed that tree with diameter of >10 cm had lower density in the edge site (391 trees per ha) than that in the interior site (470 trees per ha). Different species composition, richness, and abundance might be due to the changes in their physical environment and biotic condition such as competition in the edge site.

This study demonstrated that forest matrix, which produced edge sites, lowered peatland forest roles in sequestering carbon per unit area and reduced species density and diversity. Changing land use from peatland forest to other types of land use should consider the impact on species loss and extinction, especially at the edge or perimeter site of peatland forest. The alteration of biotic and abiotic conditions in forest edge would consequently change the tree species composition of peatland forest, even though the forests themselves were still present among other land covers. Maintaining intact forested peatland and enhancing peatland forest restoration should be conducted to reduce forest matrices and to lower the edge effects.

In conclusion, forest fragmentation established edge effects in peatland forest based on their biotic and abiotic measures under two site conditions, i.e., edge and interior parts. Changing land use from forested peatland to other types of land use must consider the impact on species loss and extinction as well as microsite condition.

Table 1. Species richness and their abundance at both Edge and Interior Sites of a tropical peatland of West Kalimantan

Species	Local name	Family	Edge site	Interior site
Actinodaphne sphaerocarpa (Bl.) Nees	Medang asam	Lauraceae	0.9	5.1
Aglaia sp.	Parak air	Meliaceae	2.2	0.3
Alangium longiflorum Merr.	Mengkapas	Alangiaceae	14.8	13.0
Alseodaphne ceratoxylon Kosterm.	Butun2	Lauraceae	1.2	0.8
Archidendron borneense (Benth.) Nielsen.	Saga rawa	Fabaceae	0.6	1.0
Artocarpus integer (Thunb.) Merr.	Cempedak hutan	Moraceae	0.0	0.1
Artocarpus sp.	Tenggayun	Moraceae	0.9	0.0
Blumeodendron takbrai (Blume) Kurz.	Mengkajang	Anacardiaceae	6.8	15.5
Buah ular	Buah ular	-	1.5	0.0
Buchaniana arborescens Blume	Mata udang	Anacardiaceae	1.8	1.3
Buchaniana latifolia Rox.	Rengas	Anacardiaceae	0.0	0.2
Buchaniana sp.	Belebu	Anacardiaceae	1.5	2.5
Calophyllum hosei Ridley	Bintangur jangkar	Clusiaceae	1.2	3.2
Calophyllum ridleyi King & Gamble	Bintangur bulu	Clusiaceae	2.8	2.9
Calophyllum soulattri Burm. F.	Bintangur1	Clusiaceae	0.0	0.3
Campnosperma squamatum Ridl.	Terentang putih	Anacardiaceae	0.6	1.6
Cantleya corniculata (Becc) Howard.	Bedaru	Poligalaceae	1.5	5.1
Chisocheton patens Blume	Parak	Meliaceae	9.2	0.6
Choriophyllum malayanum Bth.	Ubah merah2	Euphorbiaceae	4.6	0.2
Cratoxylon glaucum Korth.	Gerunggang	Hypericaceae	0.3	4.8
Cyathocalix biovulatus Boerl.	Unang-unang1	Annonaceae	2.2	5.3
Cyathocalix sp.	Unang-unang2	Annonaceae	3.7	0.5
Dactylocladus stenotachya Oliv.	Mentibu	Rubiaceae	0.3	0.2
Dialum indum L.	Keranji	Leguminaceae	10.5	1.0
Dillenia pulchella (Jack) Gilg.	Simpur laki	Dilleniaceae	3.4	0.2
Diospyros bantamensis Koord. & Valeton ex Bakh	Kayu malam daun lebar	Ebenaceae	2.2	0.7
Diospyros maingayi (Hiern) Bakh.	Kayu malam	Ebenaceae	0.0	7.5
Diospyros maingayi (Hiern.) Bakh. 1	Kayu malam daun kecil	Ebenaceae	4.6	0.6
Durio acutifolius (Mast.) Kosterm	Durian burung	Malvaceae	0.0	0.5
Dyera costulata Hook.f. Count	Jelutung	Apocynaceae	3.4	7.9
Elaeocarpus griffithii A. Gray	Mempening	Elaeocarpaceae	11.7	25.0
Elaeocarpus mastersii King	Mentanang	Elaeocarpaceae	3.1	0.0
Elaeocarpus petiolatus (Jack) Wall. ex Steud.	Pangal	Elaeocarpaceae	0.3	7.9
Eugenia cerina Endl.	Gelam tikus	Myrtaceae	0.0	0.8
Eugenia sp.	Ubah merah3	Myrtaceae	0.6	7.7
Ficus fistulosa Reinw. Ex Bl.	Kayu ara	Moraceae	15.4	0.5
Garcinia atroviridis Griff. Et AQnders	Asam gelugur	Clusiaceae	0.0	0.6
Garcinia cf. bancana Miq.	Manggis hutan	Clusiaceae	0.6	1.5
Garcinia parvifolia Miq.	Asam kandis	Clusiaceae	2.8	2.3
Gluta wallichii (Hook.f.) Ding Hou	Meransing	Anacardiaceae	0.6	2.7
Gluta wallichii (Hook.f.) Ding Hou	Terentang merah	Anacardiaceae	0.0	2.4
Gonystylus bancanus (Miq.) Kurz	Ramin	Thymeleaceae	13.2	0.6
Gymnacranthera contracta Warb.	Kumpang1	Myristicaceae	0.0	0.1
Gymnacranthera farquhariana (Hook.f.& Thoms.) Warb.	Kumpang2	Myristicaceae	0.9	3.2
Horsfieldia crassifolia (Hook.f. & Thoms.) Warb.	Mendarahan3	Myristicaceae	0.3	0.2
Ilex cymosa Blume	Mensire	Aquifoliaceae	0.3	1.7
Jackiopsis ornata (Wall.) Ridsdale	Selumar	Rubiaceae	0.0	2.6
Knema cinerea Warb.	Mendarahan1	Myristicaceae	18.2	0.3
Koompasia malaccensis (Maingay) Benth.	Kempas	Fabaceae	0.0	5.9
Leucaena leucocephala (Lam) De Wit	Petai belalang	Leguminaceae	2.2	0.0
Litsea firma Blume	Medang kunyit	Lauraceae	16.6	0.2
Litsea gracilipes Hook.f.	Medang lendir	Lauraceae	0.0	33.1
Litsea grandis (Wall ex Nees) Hook.f.	Medang lilin	Lauraceae	34.2	0.7
Litsea lanceolata Kosterm.	Mentulang	Lauraceae	0.6	0.1
Litsea nidularis Gamble	Medang keladi	Lauraceae	3.7	17.7
Litsea resinosa Blume	Medang perawas	Lauraceae	1.5	22.5
Litsea spatulata Blume.	Medang siluang	Lamiaceae	34.5	0.1
Litsea turfosa Kosterm	Medang mali	Lauraceae	0.6	1.9
Macaranga caladiifolia Becc.	Mahang semut	Euphorbiaceae	3.7	0.3
Macaranga pruinosa (Miq.) Muell. Arg.	Mahang	Euphorbiaceae	0.6	0.9
Mangifera swintonioides Kosterm.	Kebaca	Euphorbiaceae	1.2	4.0
Melicope lunu-akenda (Gaertn.) T. Hartley	Japing-japing	Rutaceae	7.7	4.0
Mezzetia parviflora Becc.	Pisang-pisang	Annonaceae	0.6	3.5

Mezzetia sp.	Keminting hutan1	Annonaceae	0.0	2.2
Myristica iners Blume	Mendarahan2	Myristicaceae	0.3	8.3
Nauclea sp.	Menterong	Rubiaceae	0.3	0.5
Neesia purpurascens Becc.	Bengang	Bombacaceae	0.0	0.6
Neonauclea excelsa (Bl.) Merr.	Kemuning	Rubiaceae	4.3	18.4
Neoscortechnia kingii King	Ilas	Euphorbiaceae	0.6	1.7
Nephelium maingayi Hiern.	Rambutan hutan	Sapindaceae	2.2	10.5
Palaquium ridleyi King & Gamble	Nyatoh banir	Sapotaceae	14.5	1.3
Parkia singularis Miq. subsp. borneensis	Petai hutan	Fabaceae	2.8	0.8
Polyalthia glauca (Hassk.) Boerl.	Keminting hutan2	Annonaceae	1.2	0.1
Polyalthia sumatrana (Miq.) Kurz.	Unang-unang daun kecil	Annonaceae	1.2	2.5
Polyalthia xanthopetala Merr.	Pundu	Annonaceae	20.9	1.6
Polyathia sp.	Unang-unang3	Annonaceae	1.2	6.7
Pometia pinnata J.R. & G. Forst.	Kasai	Sapindaceae	6.5	30.7
Pouteria malaccensis (Clarke) Baehni	Nyatoh jangkar	Sapotaceae	5.5	0.9
Pouteria obovata (R.Br.) Baehni	Nyatoh duduk	Sapotaceae	0.9	9.4
Quercus bennettii Miq.	Empaning	Fagaceae	1.5	1.8
Sandoriccum koetjape Merrill	Japang1	Meliaceae	3.4	7.3
Santiria laevigata Blume	Gelam ijuk	Burseraceae	0.0	0.5
Santiria laevigata Blume forma *glabrifolia* H.J.Lam	Asam rawa	Burseraceae	0.3	0.7
Santiria rubiginosa Blume	Sengkuang rawa	Burseraceae	1.8	3.9
Schima wallichii Korth.	Samak	Theaceae	1.5	0.3
Semecarpus glaucus Engl.	Butun3	Lauraceae	0.9	0.6
Shorea teijsmanniana Dyer ex Brandis	Meranti batu	Dipterocarpaceae	2.8	6.7
Shorea uliginosa Foxw.	Meranti bunga	Dipterocarpaceae	5.5	17.4
Sindora sp.	Tanjan	Leguminaceae	0.0	0.9
Spondias pinnata (L.F.) Kurz.	Kedondong hutan	Anacardiaceae	4.9	0.3
Stemonurus scorpioides Becc.	Mempasir daun lebar	Icacinaceae	8.6	15.0
Stemonurus secundiflorus Blume	Mempasir daun kecil	Icacinaceae	0.3	9.9
Syzigium sp.1	Ubah jangkar	Myrtaceae	6.2	0.6
Syzygium lineatum (DC.) Merr. & L.M. Perry	Ubah merah1	Myrtaceae	0.0	17.4
Syzygium sp.2	Ubah putih1	Myrtaceae	4.3	15.5
Syzygium *zollingerianum* (Miq.) Ams.	Ubah jambu	Myrtaceae	0.9	6.1
Tabernaemontana macrocarpa Jack	Butun1	Apocynaceae	0.0	0.1
Tetractomia tetrandra Craib.	Ubah putih2	Rutaceae	12.0	4.3
Tetramerista glabra Miq.	Punak	Tetrameritaceae	3.4	23.2
Tristaniopsis cf. merguensis (Griff.) Peter G.Wilson & J.T.Waterh	Pelawan putih	Myrtaceae	0.3	0.3
Vatica mangachapoi (Blanco) Bl.	Resak	Dipterocarpaceae	0.0	0.7
Vitex secundiflora Hallier f.	Leban	Verbenaceae	1.8	0.7
Xanthophyllum ellipticum Korth. ex Miq.	Menjalin	Polygalaceae	5.8	0.0

ACKNOWLEDGEMENTS

We thank the people of Desa Kuala Dua, Kubu Raya District, West Kalimantan Province, Indonesia for their involvement in some study works in peatland forest near their communities. Great appreciations went to Fellows in Landscape and Livelihood Indonesia, World Wildlife International, Fauna Flora International-Indonesia Programme who supported our works in many incredible ways and endless help. Great thanks delivered to many others which could not be personally listed, but had provided much assistance to accomplish this study.

REFERENCES

Astiani D, Burhanuddin, Curran LM, Mujiman. 2017b. Drainage ditches establishment on peatland forest landscape: Effects on water table levels, soil conditions and tree growths of West Kalimantan peatland degraded forests. Indon J For Res 4 (1): 15-25

Astiani D, Mujiman, Lisa M Curran. 2017a. Trees of West Kalimantan-Peatland Forest Influence on Variability of Water and Carbon Input through Stemflow Mechanism. Biodiversitas 18 (1): 383-388.

Astiani D, Mujiman, Salim R, Hatta M, Firwanta DD. 2015. Tropical peatland forest degradation: Effects on forest regeneration biomass, growth, mortality, and forest microclimate conditions. In: Azhar I, Hartono R, Iswanto AH, Hartini KS, Susilowati A, Elfiati D, Muhdi (ed.). Proceeding the 6th International Symposium of Indonesian Wood Research Society, Medan, Indonesia.

Astiani D, Ripin. 2016. The role of community fruit garden (tembawang) on maintaining forest structure, diversity and standing biomass allocation: an alternative effort on reducing carbon emission. Biodiversitas 17 (1): 359-365.

Astiani D. 2014. Bornean Peatlands: Forest Dynamics, Land Use and Carbon Flux. [Dissertation]. Graduate School of Yale University, USA.

Astiani D. 2016. Tropical peatland tree species diversity altered by forest degradation. Biodiversitas 17 (1): 102-109.

Bierregaard R. 2001. Claude Gascon; Thomas E. Lovejoy; Rita Mesquita (eds) in Lessons from Amazonia: The Ecology and Conservation of a Fragmented Forest. Yale University Press, New Haven, CT.

Brown S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper No. 134. FAO, Rome.

Brown S. 2002. Measuring carbon in forests: current status and future challenges. Env Pollut 116: 363-72.

Cadenasso ML, Pickett STA, Weathers KC, Jones CG. 2003. A framework for a theory of ecological boundaries. Bioscience 53: 750-758
Celine E, Philippe M, Astrid V, Catherine B, Musampa C, Pierre D. 2013. Nasional forest cover change in Congo Basin: Deforestation, reforestation, degradation and regeneration for the years 1990, 2000 and 2005. Glob Ch Biol 19: 1173-1187.
Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D Foster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Rie´ra B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145 (1): 87-99.
Clark DA, Brown S, Kicklighter DW, Chambers JQ, Thomlinson JR, Ni J. 2001. Measuring net primary production in forests: Concepts and field methods. Ecol Appl 11 (2): 356-370.
Grainger A. 1993. Controlling Tropical Deforestation. Earthscan, London.
Harper KA, MacDonald SE, Burton PJ, Chen J, Brosofske KD, Saunders SC, Euskirchen ES, Robert D, Jaiteh MS, Eseen P. 2005. Edge influence on forest structure and composition in fragmented landscapes. Conserv Biol 19 (3): 768-782.
Harris LD. 1984. The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity. University of Chicago Press, Chicago, IL.
Hooijer 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.
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 Report Q3943. Delft, Nederland.
Jaenicke J, Rieley JO, Mott C, Kimman P, Siegert F. 2008. Determination of the amount of carbon stored in Indonesian peatlands. Geoderma 147: 151-158.
Lambin, EF. 1999. Monitoring forest degradation in tropical region by remote sensing: some methodological issues. Global Ecol Biogeog 8: 191-198.
Macquarrie K, Lacroix C. 2003. The upland hardwood component of Pince Edward Island's remnant Acadian forest: determination of depth of edge and patterns of exotic plant invation. Can J Bot 81: 1113-1128.
Maltby E, Immirzi P. 1993. Carbon dynamics in peatlands and other wetland soils: Regional and global perspectives. Chemosphere 27: 999-1023.
Margono BA, Turubanova S, Zhuravleva, Potapov P, Tyukavina A, Baccuni A, Goetz S, Hansen MS. 2012. Mapping and monitoring deforestation and forest degradation in Sumatera (Indonesia) using Landsat time series data sets from 1990 to 2010. Env Res Let 7: 1-16
Miettinen J, Shi C, Liew SC. 2011. Influence of peatland and land cover distribution on fire regimes in insular Southeast Asia. Regional Env Ch 11: 191-201.
Murcia C. 1995. Edge effects in fragmented forest: Implication for conservation. Tree 10 (2): 58-62.
Paoli GD, Curran LM, Slik JWF. 2008. Soil nutrients affect spatial patterns of aboveground biomass and emergent tree density in southwestern Borneo. Oecologia 155: 287-299.
Rheault H, Drapeau P, Bergeron Y, Esseen PA. 2003. Edge effects on epiphytic lichens in managed black spruce forest of eastern North America. Can J For Res 33: 23-32.
Rieley JO and Page SE (eds). 2005. Wise Use of Tropical Peatland: Focus of Southeast Asia. ALTERRA-Wageningen University and Research Center and the EU INCO-STRAPEAT and RESTORPEAT Partnership, Wageningen.
Saatchi SS, Harris NL, Brown S. 2011. Benchmark map of forest carbon stocks in tropical region across three continents. Proc Nat Acad Sci USA 108: 9899-9904.
Sizer N, Tanner EVJ. 1999. Responses of woody plant seedlings to edge formation in a lowland tropical rainforest Amazonia. Biol Conserv 91: 135-142.
Uryu Y, Mott C, Foead N, Yulianti K, Setiabudi, Takakai F, Nursamsu, Sunarto, Purastuti E, Fadhil N, Hutajulu CMB, Jaenicke J, Hatano R, Siegert F, Stuwe M. 2008. Deforestation, forest degradation, biodiversity loss, and CO_2 emission in Riau Sumatra, Indonesia. Technical Report. WWF Indonesia, Jakarta.
Van der Werf GR, Morton DC, DeFries RS, Olivier JGJ, Kasibhatla PS, Jackson RB, Collatz GJ, Randerson JT. 2009. CO_2 emission from forest loss. Nat Geosc 2: 737-738.
Wood TE, Cavaleri MA, Reed SC. 2012. Tropical forest carbon balance in warmer world: a critical review spanning microbial-to ecosystem-scale processes. Biol Rev 87: 912-927.