BIODIVERSITAS
Volume 18, Number 1, January 2017
Pages: 137-144

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d180120

Forest type diversity on carbon stocks: Cases of recent land cover conditions of tropical lowland, swamp, and peatland forests in West Kalimantan, Indonesia

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Manuscript received: 31 July 2016. Revision accepted: 25 November 2016.

Abstract. *Astiani D, Mujiman, Rafiastanto A. 2017. Forest type diversity on carbon stocks: Cases of recent land cover conditions of tropical lowland, swamp, and peatland forests in West Kalimantan, Indonesia. Biodiversitas 18: 137-144.* Tropical forests constitute for a large concentrated carbon pools, ultimately in tropical peatland forest since this forest type sink carbon both in the vegetation and its underlying peat. However, these forests recently experienced a lot of pressures from anthropogenic disturbances. A study was conducted to estimate carbon stocks of degraded tropical lowland, swamp, and peatland forests in Kayong Utara West Kalimantan. Above ground survey was conducted using stratified sampling based on the differences in spectra of Landsat 7 ETM+ according to the land cover gradation or vegetation formations. The study area was classified based on the canopy closures and forest/landcover types and grouped into low and high degraded lowland forest, low and high degraded peat forest, low and high degraded swamp forest, shrub land, and mixed agricultural land. Aboveground carbon stocks in each group was estimated by purposively assessing all carbon sources within 5-11 plots of 20 m x 100 m area. Belowground carbon was also measured on peatland. Results show that among the groups, the highest to the lowest order of aboveground carbon sink consecutively were low degraded swamp, low degraded lowland, low degraded peatland, high degraded swamp, high degraded peatland, high degraded lowland forests, mixed agricultural land, and shrub land (269.1 to 46.3 ton C/ha) plus other biomass sources recruited from belowground roots. It is demonstrated that forest degradation and land cover changes reduce amount of above ground carbon stocks and thus could result large amount of carbon loss from forests. Surprisingly, our results demonstrated that 0.5-5.2 m belowground carbon in peatland contribute to large amount of carbon Each meter depth of those fibrist to hemist peat sinked ~634 ton C/ha. It is estimated that the 22,600 ha area of overall forest types/ land covers sink ~2.5 million of aboveground and ~5,570 ha peatland area hold ~9.2 million of below ground carbon. This amount of carbon is potential sink of carbon yet could be a huge losses if peatland forest and land cover changes continued.

Keywords: Aboveground carbon, belowground carbon stocks, degraded forest, land cover change, forest types

INTRODUCTION

Tropical forests provide an enormous roles to environment ecosystem not only to local people but also to global population such as habitat biodiversity, hydrology regulator, and carbon storage. They have a significant role in storing huge amounts of carbon. They store the carbon in above ground biomas, as well as in belowground. Tropical forests fix large amount CO_2 from atmosphere through photosynthesis and store carbon as biomass. However, the ecosystem recently deserve special attention because of continuing considerable degradation and destruction (Celine et al. 2013).

The destruction of tropical peatland ecosystem not only on the above ground vegetation, but it was destruct also below ground peat soil (Don et al. 2011; Welloct et al. 2011) 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 (Achard et al. 2002; Miettinen et al. 2011). 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) .

Forest degradation could bring the forests into small, unsignificant, a temporary shifting or could cause large, very significant, permanent destruction. The changes are not only in forest vegetation density, structure, and their potential to stock and emit carbon but also in species composition. The condition could lead to reduce their productivities (Lambin 1999; Astiani 2016; Astiani et al. 2016). Since tropical forests play a major role in regulating global carbon, fluxes and stocks-especially in peatland (Anderson 1983; Maltby and Immirzi 1993; Brown 2002; Hooijer et al. 2010), even a very small alteration to carbon balance in a biome, could have a significant 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 is threatening forest CO_2 sequestering function of forest (Jaenicke et al. 2008; Saatchi et al. 2011), and deforestation and degradation account for approximately 12% of global GHG emission (Van der Werf et al. 2009).

Tropical forest in Indonesia has most extensive and biologically diverse tropical forests in the world. However, most of its forest types had been degraded. It is important to reveal how forest degradation within different forest types impact on their roles in storing carbon. To improve estimates of forest role in maintaining carbon stocks of recent West Kalimantan forest condition, our study was designed to estimate current carbon stocks of variably land covers occupying a large landscape of mixed forest types and land covers and concurrently with belowground carbon stocks of peatland in Kayong Utara in West Kalimantan, Indonesia.

MATERIALS AND METHODS

Site selection

The areas of carbon assessment were located in between 110^0 10' 0” E to 110^0 22' 80” E and 0^0 65' 0” S to 1^0 65' 0” S in S Matan, Kabupaten Kayong Utara, West Kalimantan, extending ~ 22,600 ha within PT Citra Usaha Lestari (CUS) oilpalm concession, covered with mixed forest type, agriculture (1-3 years old oilpalm) area. shrub land and open area (Figure 1). Below ground carbon assessment was located in the middle northern block and Middle East corner block of concession area which covered by peatland forest (5,576 ha). This area was chosen based on the indication of peat land area derived from satellite image interpretation and soil map. Above ground carbon assessment was distributed throughout the area based on the stratified land cover/forest types, however we found swamp forest in a form of small patches interspaced within peatland forest and difficult to deliniate the area in the map. therefore on estimating overall carbon stocks in the area, the carbon-stock calculation was interpreted base of field finding and estimation. Below ground carbon assessment was focused in peatland area.

Sampling approaches

Above ground survey was conducted using stratified sampling based on the differences in spectra interpretation of Landsat Image according to the land cover or forest types. The area was classified and refined based on land cover types in the area: low degraded lowland (LDLF), high degraded lowland (HDLF), low degraded peatland (LDPF), high degraded peatland forest (HDLF), low degraded swamp forest (LDSF), high degraded swamp forest (HDSF), mixed agriculture (mixed crops, oilpalm), and shrub covered lands (Figure 2) .

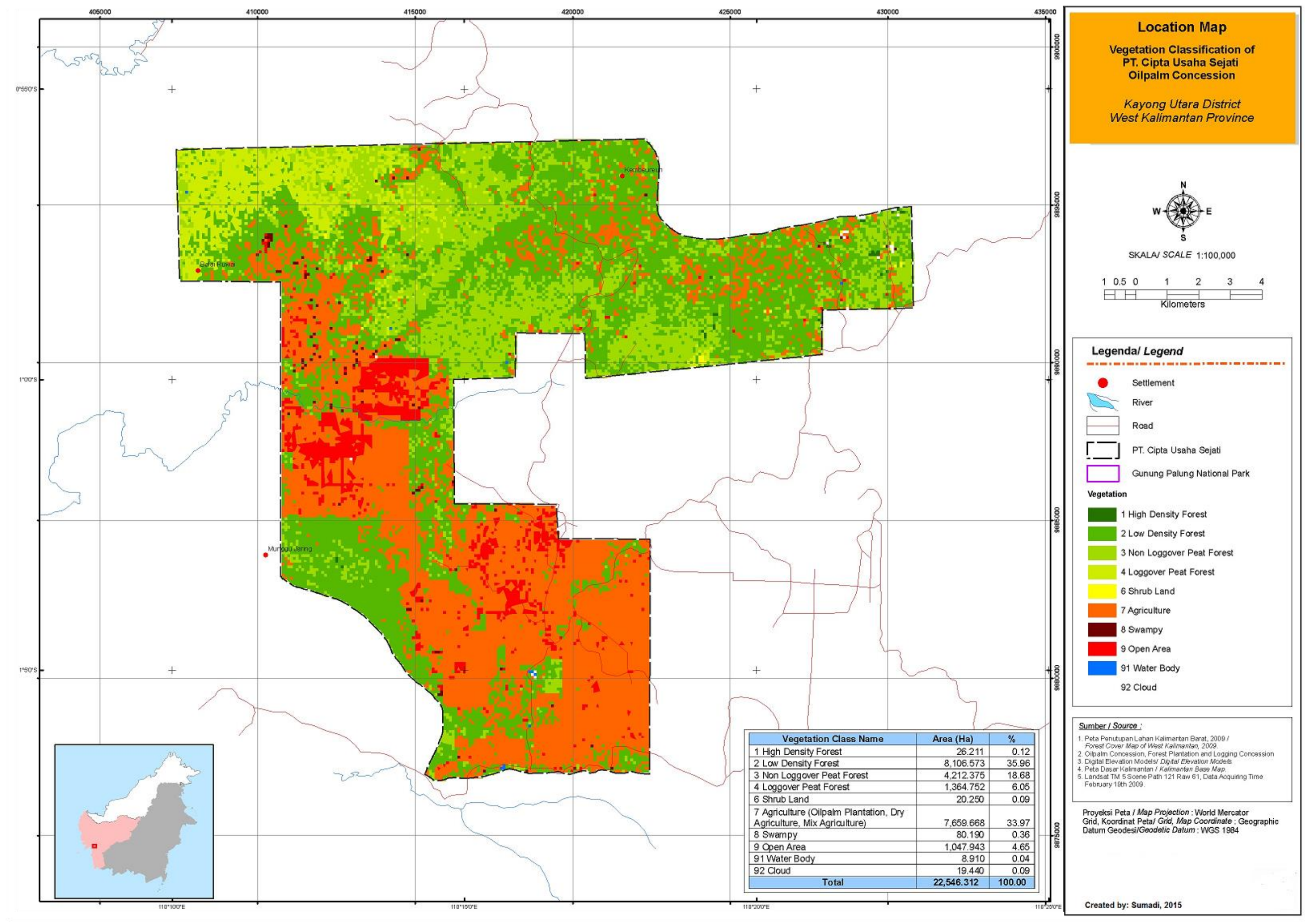

Figure 1. Research site in Kayong Utara District of West Kalimantan, Indonesia

Within each land cover stratification, we purposively measured 9-12 plots of a 20 m x 100 m size for aboveground carbon estimates and, under peatland area, we also assessed below carbon stocks. In each plot we measured 5 carbon pools: tree diameter >20 cm within 20 m x 100 m area; tree diameter >5 cm and <20 cm within 5m x 40 m nested plot; necromass (standing woody debris, CWD, stumps) within nested plot of 5 x 40 m; ground storey 4-6 1 m x 1 m nested plots; and litter, 4-6 0.5m x 0.5 m nested plots. Except for ground storey vegetation and litter sampling which using destructive technique, all sampling measurement on forest vegetation were using non destructive methods (Figure 3). To estimate tree and necromass biomass, we used allometric equations generated by Brown (1997); Chave et al. (2005); and Puhlin (2009).

Based on peat area indication maps, we produced a sketch map describing planned transects to be measured. Within each transects we took measurement using systematic sampling and the points sampled were applied to estimate peat biomass. We measured 85 peat profile and depth and 12 peat cores were sampled to represent peat characteristics and brought to laboratories for further analysis. Throughout each plot, we measured tree diameters, tree heights, and identified tree species names (for tree wood density identification). For Necromass (Coarse Woody Debries), we measured dead stem's diameter, length, and level of decomposition (1, 2, and 3). Then, necromass volume were quantified by cylinder equation. We brought 5 of each class wood samples to classified wood density of class 1, 2, and 3 and their dry bulk masses at laboratory. Necromass' biomass was volume x wood density. We also sampled leaf litters and understorey vegetation and took about 300 g samples of each measurement for oven dry weight and C content at laboratory.

For assessing below ground peat, peatland area indication was derived from overlaying study area, soil and vegetation maps. Based on the indication maps, a sketch map describing planned transects to be measured were planned and produced. Along main transect that approximately crossing indicated peat dome, we designed East-West or North-South orientation branch transects which were perpendicular to the main transect within 2 km distance, so called 'fish bone' transects. Within each transects we took measurement using systematic sampling

Figure 2. Forest type/land cover variation on the study area, A. Shrubland, B. Agricultural Land, C. Low degraded Lowland forest, D. High degraded Lowland Forest, E. Low degraded Swamp forest, F. High degraded Swamp forest, G. Low degraded peatland forest, H. High degraded peatland forest

Figure 3. Below and aboveground carbon assessment activities

and the points sampled were applied to estimate peat biomass. For this study, we measured peat depth systimatically within 500 m distances. Peat soil core samples were taken systematically on each 2 km distance for further laboratory analysis (bulk density, water and ash contents, and organic carbon). We measured 85 peat profile and depth and 12 peat cores were sampled to represent peat characteristics and brought to laboratories for further analysis.

Below ground carbon in other two forest types were not intensively sampled. Our previous finding on carbon stocks under lowland forest and swamp forest were relatively low. We included soil carbon contents on both forest type for comparison.

Data analysis

Biomass of trees diameter >5 cm were estimated using Chave (2005) equation which involved tree wood-specific gravities. Each data was presented as total (species composition) or mean and standard error. The comparation among eight landcover was compared using multiple T Test.

RESULTS AND DISCUSSION

Land cover/forest type conditions

Recent condition of each land cover/forest type were approached by quantifying tree with diameter >5 cm basal areas and their dominant species on each type. Landcover/forest type description of recent condition is presented in Table 1.

The highest basal area found in low degraded swamp forest and the least in agriculture land vegetation . Recent condition indicate that there were decreasing in basal area of each landcover type when forests were degraded. The reduction of basal area were 38.7%. 26.3%. and 42.7% respectively on lowland, peatland and swamp forests. There was also a significant shifting on the spesies dominated on each forest type when degraded. The most significant dominant species change found in lowland forest, dominant species were replaced by fruit garden. However, Astiani and Ripin (2016) revealed that old fruit garden (>100 years) established on lowland forest allocated large amount of biomass on the trees as well.

Table 1. Recent landcover/forest-type description from field assessment

Land cover/ Forest type	Mean basal area ± SE (m^2 ha^{-1})	Dominant species
Low Degraded Lowland	37.78 ± 3.14	Sungkai (*Peronema canescen* Jack), ubah merah (*Syzygium lineatum* (DC.) Merr. and L.M. Perry, ubah putih (*Tetractomia tetrandra* Craib.), pangal (*Elaeocarpus petiolatus* (Jack) Wall. ex Steud.), medang (*Litsea firma* Hooks), mendarahan (*Horsfieldia crassifolia* (Hook.f. and Thoms.) Warb.), ulin (*Eusideroxylon zwageri* Teijsm. and Binn)
High Degraded Lowland	23.17 ± 1.21	Durian (*Durio zibethinus* L.), karet (*Hevea brasiliensis* Muell. Arg), cempedak (*Arthocarpus integer* (Thunb) Merr), lansat (*Lansium domesticum* Corr.), mentawak (*Arthocarpus anisophyllus* Miq.), pekawai (*Durio kutejensis* Hassk. Becc)
Low Degraded Peatland	36.25 ± 2.06	Gelam tikus (*Eugenia cerina* Endl.), gerunggang (*Cratoxylon glaucum* Korth.), jungkang, kayu malam (*Diospyros maingayi* (Hiern.) Bakh.), leban paya (*Vitex secundiflora* Hallier f.), medang asam (*Actinodaphne sphaerocarpa* (Bl.) Nees), medang perawas (*Litsea resinosa* Blume), nyatoh (*Palaquium ridleyi* King and Gamble), perupuk (*Lophopetalum javanicum* (Zoll.) Turcz)
High degraded Peatland	26.71 ± 0.57	Leban paya (*Vitex secundiflora* Hallier f.), perepat (medang keladi (*Litsea nidularis* Gamble), ilas (*Neoscortechnia kingii* King , jelutung (*Dyera costulata* Hook.f. Count) , keminting hutan (*Polyalthia glauca* (Hassk.) Boerl), mempasir (*Stemonurus scorpioides* Becc.),
Low Degraded Swamp	49.71 ± 3.43	Bintangor (*Calophyllum ridleyi* King and Gamble), kayu malam (*Diospyros maingayi* (Hiern.) Bakh.), mensire (Ilex cymosa Blume), ubah bentan (*Syzigium* sp., ramin (*Gonystyllus bancanus* Miq, ubah putih (*T. tetrandra* Craib.)
High Degraded Swamp	28.50 ± 1.35	Kasai (*Pometia pinnat*a J.R. and G. Forst.), bintangor (*C. ridleyi* King and Gamble), kayu malam (*D. maingayi* (Hiern.) Bakh.), mengkubung (*Macaranga gigantea* Reichb. f and Zoll), nyatoh banir (*Palaquium ridleyi* KingandGamble), mengkapas (*Alangium longiflorum* Merr.), keminting hutan (*P. glauca* Hassk. Boerl)
Shrub	1.68 ± 0.57	Leban (*Vitex pubescen* Vahl), mahang (*Macaranga gigantea* Mull.Arg), jengkol (*Archidendron pauciflorum* (Benth IC Nielsen), jarak api (*Aglaia rubiginosa* (Hiern) Pannell.)
Agriculture	0.9 ± 0.73	Fern, mixed crops, pineapple, cassava, oil palm, vegetables and paddies

Table 2. Total aboveground carbon with additional estimated root carbon

Land cover	Total above ground C pools (t/ha)	Estimate root carbon t/ha*	Total C t/ha	% of root carbon
Low degraded lowland	204,54	34,77	239,31	17
High degraded lowland	107,14	20,36	127,50	19
Low degraded peatland	192,83	32,78	225,61	17
High degraded peatland	142,72	25,69	168,41	18
Low degraded swamp	269,18	45,76	314,94	17
High degraded swamp	161,47	29,06	190,53	18
Shrub	46,31	9,26	55,57	20
Agriculture	57,41	11,48	68,89	20

Note: *Estimated using Brown (2002)

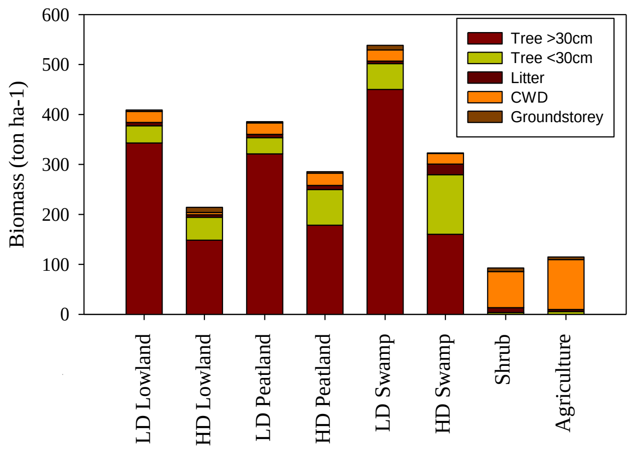

Figure 4. Above ground biomass of forests (Low degraded-LD, and high degraded-HD) and land cover types per ha within each of their carbon source in Kayong Utara landscape

Above ground biomass and carbon stocks

Carbon stock of each forest and land cover types distribution varied significantly, depend on recent condition. The distribution of biomass measured on each carbon pool for each land cover type is presented in Figure 4.

Results show that forest degradation, beside it shifted forest structure spesies composition (Astiani 2016), it reduced carbon stock of each forest type. Lowland, peatland, and swamp forest reduced their stand biomass by 58%, 31%, and 26% consecutively. The biomass quantity losses approximately depend on degrees of forest degradation. Eventhough some indigenous species could regrowth even in very insufficient physical and fertility soil (Ekyastuti et al. 2016), the tree biomass grow very slow. Forest land use changes to oilpalm (3 years old) and shrub land decreased aboveground biomass by ~75-86%. On agriculture and shrub land, however, the highest proportion of carbon are stocked in CWD pools (above 85 %), where the stocks are potentially decomposed and be emitted to the atmosphere.

Biomass allocation of each landcover/forest type was dominated mostly by living tree biomass (especially diameter >30 cm), with exception in agriculture and shrub areas, where less or none of living tree found. Necromass (CWDs and litters) significantly determined biomass stocks in agriculture and shrub areas. Estimated carbon stocks were using default carbon value of 50% of biomass (Brown 1997). Higher carbon stocks were in low degraded swamp forest, low degraded lowland forest, and low degraded peatland forest (256, 207, and 193 ton C/ha consecutively) and the least carbon stocks was found in shrubland areas (46 ton C/ha). Most of living biomass of the eight landcover/forest classes are potentially hold significant percentage of carbon (Mean ± SE = 90% ± 1.6%). In general about 87% ± 1.3% of carbon stocks are sequestered in living trees (diameter 5 cm and above), and in small amout squestered in groundstorey (~3%).

Roots carbon stocks estimate approaches

In addition to aboveground biomass, we estimate root carbon stock by presenting above ground biomass data using allometric equation following Brown (2002). The approaches resulted that there are additionally 17% to 20% of carbon stocks are sequestered below ground in the vegetation roots.

Total carbon stocks (both above ground and root stocks) in this area were much higher than estimates of forests in tropical Asia (151 t C/ha) and also in the range by IPCC (2011) estimates of carbon stocks in tropical equatorial forest which were 182-225 t C/ha (Gibbs et al. 2007), except for agriculture, shrubs land, and high degraded lowland, which was a young 'tembawang' forest. In tembawang, surround people communities maintained multi purpose trees and crop for relatively longer time, more than 100 years (Roslinda 2016; Astiani and Ripin 2016), Therefore the amount of carbon sink will gradually increased and will be standing for 3-4 future generation

These measures were more reliable since we had stratified the mixed forests into smaller type od forests or land cover conditions and more througout sampling sites. Even though agriculture and shrubs areas have less total carbon, yet they also contribute to carbon sequestration and cycling. To make projection of the carbon stocks on a larger landscape scale of the area, we present the estimated aboveground carbon for overall coverage area by extrapolating carbon stock per unit are to the overall area of each land cover type by GIS map interpretation. The estimate is presented in Table 3.

Among forest types in the extend of forest landscape, it indicates that each forest type sequestered various above ground carbon stocks. The values were ranged from the lowest of 37 ton ha^{-1} (shrub land) to the highest of 256 ton ha^{-1} in low degraded swamp forest, with overal mean of 117.2 ton ha^{-1}. High degraded forest of each of the three forest types maintained various but lower carbon stock quantities. The important point to learn was that forest degradation reduced the role of tropical forest to maintain carbon stocks in their stand biomass per unit area by 58%, 31%, and 26% respectively for lowland, peatland, and swamp forests.

Table 3. Estimated carbon stocks at mixed landcover/forest type landscape of Kayong Utara, West Kalimantan, Indonesia

Land cover types	Area of land cover types (ha)	Total biomass pools (t/ha)	Above ground C pools (t/ha)	Estimate root carbon t/ha	Total C t/ha	Above ground carbon (t)	Above ground C + estimated root C (t)
HDLF	26.21	413.51	206.76	35.45	242.20	5,419.39	6,348.30
LDLF	8,106.57	172.11	86.06	16.35	102.40	697,651.70	830,113.08
HDPF and HDSF	4,212.38	415.15	207.58	35.58	243.16	874,404.80	1,024,281.10
LDPF and LDSF	1,364.75	273.84	136.92	24.60	161.52	186,861.80	220,434.74
SH	20.25	61.21	30.61	6.26	36.87	619.80	746.62
AG	7,659.67	92.63	46.31	9.29	55.60	354,719.20	425,877.54
Total							2,507,801.40

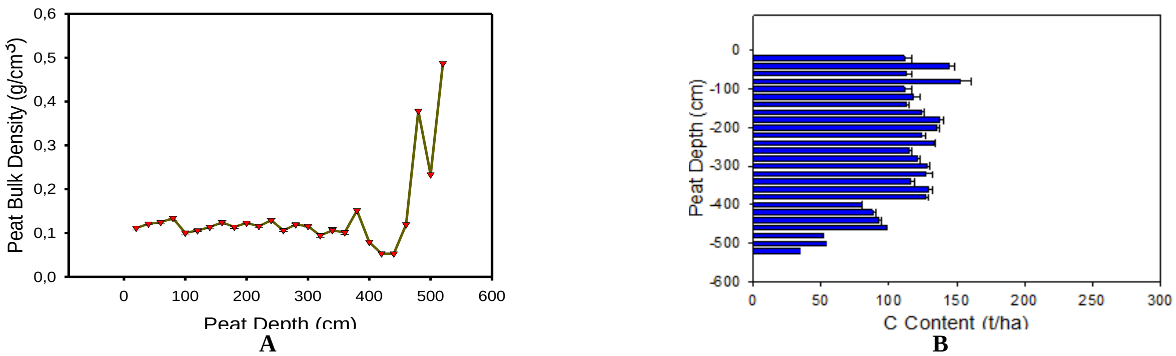

Figure 5. A. Bulk Density distribution g cm^{-3}; and B. Carbon stocks each 20 cm of depth in peatland profile (Mean and SE-ton/ha)

Agricultural land (1-3 year old) sequestered a relatively equal amount to shrubs lands (3 year old sequestered 48 ton ha^{-1} carbon). Mean annual growth level added about 14-18 ton ha^{-1} carbon to the oil palm plants, while shrub land maintain 37 ton ha^{-1}. Compared to forests, these land covers were a lot less in holding biomass stocks. It showed that land cover changes from forests affected on considerably large portion of above carbon losses.

Belowground carbon stocks

Peat area was vary with depth from 0 m to 5 m and mostly classified as *fibrist* peat. Peatlands are commonly interspersed in small hill of lowland area, which sometimes found abrupt. This terrain condition is especially around the perimeter of peat land in the southern part of assessment area. Deeper peat depths ranges found in northern area of the concession landscape. Upon laboratory determination of peat bulk density of peat samples, the mean analysis results of bulk density and mean peat carbon per 20 cm depths samples is presented in Figures 5.A and 5.B.

Peat bulk density was relatively constant along the vertical peat profile, yet increased rapidly when reached mineral soil under the peat layers, therefore, the peat soil biomass was relatively not vary along the 20 cm peat depths except at the last layers that were mixed with mineral soil beneath peat layers.

Table 4. Carbon stocks accumulation on peat depth profile

Peat core depth	Mean carbon ton ha^{-1} per 20 cm peat depth	SE	Peat carbon accumulation ton ha^{-1}
00-20	111.56	5.14	116.70
20-40	144.80	3.77	256.36
40-60	112.98	4.10	369.34
60-80	152.71	8.19	410.49
80-100	111.63	5.11	633.68
100-120	117.99	5.31	751.67
120-140	112.34	2.29	864.02
140-160	124.25	1.70	988.27
160-180	137.51	2.95	1125.78
180-200	135.27	2.01	1261.05
200-220	124.24	2.60	1385.29
220-240	132.75	1.20	1406.48
240-260	115.18	1.70	1633.23
260-280	121.36	1.42	1754.59
280-300	128.20	2.39	1882.79
300-320	127.26	4.83	2010.05
320-340	116.23	2.80	2126.28
340-360	128.94	3.45	2255.22
360-380	126.96	2.03	2382.18
380-400	79.87	0.88	2462.05
400-420	87.92	2.06	2549.97
420-440	92.38	2.31	2642.35
440-460	99.07	0	2741.43
460-480	51.33	0	2792.76
480-500	34.38	0	2827.14
500-520	25.56	0	2852.70

Total below ground carbon in peatland landscape reached 2853 ton ha^{-1} within 5 m peat depth or in the average of 570 ton ha^{-1} (Table 4). Compared to other two forest types, lowland and swamp forest, the carbon amount in peatland was much more abundant. Our previous results on carbon stock in lowland forest and swamp forest within 1 meter soil depth were 0.06 ± 0.003 and 0.64 ± 0.02 ton ha^{-1} respectively and reduced within the deeper solum. The results demonstrate that peatland forests is trully potential carbon storage in nature.

Projected estimate of total aboveground carbon within overall landscape, which covered by several types of landcovers and forests, was about 2.5 x 10^6 ton. However, compared to peat soil carbon below the peatland forest, the carbon sinked in the area was far less. The peat depth varied between 0.3 to 5.2 m. For below carbon stock of peatlands in the area was ~625 ton ha^{-1} m^{-1} depth, and total ~9.2 million ton C $h^{-1}a$ maintained in 5,570 ha peatland area.

Peatlands in the landscape were found scattered and interspersed in small hill of lowland area, which sometimes found abrupt. This total carbon stock in peatland soil was relatively moderate for *fibrist* peat, yet it is huge amount compare to other forest types.. The amount of carbon stock in peat layers may vary depend on the peat decomposition level, which dictated peat bulk density, proportion of carbon in organic matters amount per unit weight, and peat depth. It is demonstrated that belowground carbon in this tropical peatland hold more than 10 times of above ground carbon sequestered in living and dead biomass.

It is important to maintain and sustainably use of those forests on the landscape thoroughly. Partial plan or management could couse impact to other parts of the forest landsacape. Lowland, swamp, and peatland forest ecosystem were diverse in their species composition and density, yet they keep relatively high forest biomass for carbon stocks, especially in peatland forest. Those forests in the Kayong Utara, West Kalimantan, Indonesia lansdscape need to be managed well and responsibly to avoid CO_2 emission/carbon loss from landscape and additional sources GHGs to the atmosphere that could enhance global warming.

ACKNOWLEDGEMENTS

First, we would like to thank people of villages surround PT CUS consession landscape, who incredibly were supporting us in doing field assessment. We would like to thanks the consession, for their supports and facility, these companies allow us to conduct part of our field works within their oil palm concession. With daily field works tasks, we are eternally in debts people who works and share with me outstanding experiences. Special thanks to Fauna Flora International (FFI)-Indonesian Programme, Jakarta that facilitated and made this works possible. We express my deepest gratitude to all fellows in FFI and Landscape and Livelihood Indonesia Institute, Pontianak who were so supportive during the process of this study.

REFERENCES

Achard F, Eva HD, Stibig HJ, Mayaux P, Gallego J, Richards T, Malingreau JP. 2002. Determination of deforestation rates of the world’s humid tropical forests. Science 297 (5583): 999-1002.

Anderson JA.R. 1983. The tropical peat swamps of Western Malaysia. In: Gore AJP (ed.) Ecosystems of the World 4B, Mires: Swamp, Bog, Fen and Moor, Regional Studies. Elsevier, Amsterdam.

Astiani D, Burhanuddin, Taherdjadeh M, Curran LM. 2016b. Effects of water table level on soil CO_2 respiration in west kalimantan peatland: an experimental stage. Nusantara Biosci 8 (2): 201-206

Astiani D, Ripin. 2016c. The Roles of community fruit garden (tembawang) of desa cempedak kabupaten sanggau on maintaining species diversity and standing biomass: An alternative effort on reducing carbon emission. Biodiversitas 17 (1): 359-365.

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

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 Environ Pollut 116: 363-72.

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 Change 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, Riera B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145 (1): 87-99.

Don A, Schumacher J, Freibauer A. 2011. Impact of tropical landuse change on soil organic carbon stocks-a meta analysis. Glob Change Biol 17: 1658-1670.

Ekyastuti W, Astiani D, Roslinda E. 2016. Prospect of indigenous plant species for revegetation in the tailings area of ex community gold mine. Biodiversitas 17 (2):764-768.

Gibbs HK, Brown S, Niles JO, Foley JA. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environ Res Lett 2. DOI:10.1088/1748-9326/2/4/045023.

Hooijer A, Silvius M, Wösten H, Page SE. 2006. PEAT-CO2, Assessment of CO_2 emissions from drained peatlands in SE Asia. Delft Hydraulics report Q3943. The Nederlands.

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. 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.

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. Glob Ecol Biogeogr 8: 191-198.

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 I, 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 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 Environ Ch 11 191-201.

Puhlin H. 2009. Methods in Assessing Carbon Stocks. Forest Carbon Project Development Training Program. World Agroforestry Centre, Bogor.

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

Roslinda E. 2016. Dayak Desa forest landuse system as social capital to acquire forest management rights in West Kalimantan, Indonesia. Biodiversitas 17 (1): 177-184.
Saatchi SS, Harris NL, Brown S. 2011. Benchmark map of forest carbon stocks in tropical region accross three continents. Proc Nat Acad Sci USA 108: 9899-9904.
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. WWF Indonesia Technical Report, 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 Geosci 2: 737-738.
Wellock M, Reidy B, Laperle CM, Bolger T, Kiely G. 2011. Soil organic carbon stocks of afforested peatland in Ireland. Forestry 4 (4): 441-451.
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.