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THE EFFECT OF LAND USES ON SELECTED PEAT PROPERTIES THAT CONTROL CARBON STORAGE IN A MASSIVELY DRAINED TROPICAL PEAT DOME

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SUMMARY

Tropical peats in Indonesia are important for carbon storage, but land use changes cause substantial decline of carbon stock. This study aims to assess impacts of land uses on selected peat properties that importantly control carbon stock. The study site is located in a massively deforested and drained peat dome, presently called Rasau Jaya in West Kalimantan Province, Indonesia. This peat dome was firstly logged in early 1970, drained and converted into agriculture development in 1972. Land uses consist of secondary forest (DF), open peat (BF), and oil palm plantation (OP). A total of 160 peat samples, each 100 cm^3, were analyzed. Research variables consist of bulk density (BD), Total organic carbon (TOC) and total nitrogen (TN). We also analyzed organic matters through loss on ignition (LOI). Then, C/N ratio, C and N densities (CD and ND) were calculated. We used one-way ANOVA to assess mean differences of these variables following land uses (sites) and control sections of peat thickness. If results of ANOVA showed significant, we used Games-Howell post-hoc tests, with a set of orthogonal contrasts. Results of this research show that land uses generally does not significantly alter peat properties, but leads to increases in CD and ND, in particular, on oil palm plantations due to substantial increases of bulk densities. Vertically, peat properties in the surface and sub-surface tiers (0-100 cm and 100-200 cm) are highly significantly different from the below and bottom tiers (200-300 cm and >300 cm). We recommend monitoring carbon stock in the upper 200 cm thickness section, as this section suffers most from anthropogenic land use changes in tropical peats.

Keywords: *Land use changes, Tropical peat degradation, Carbon storage, Human disturbances*

INTRODUCTION

Tropical peats are mainly found in Indonesia. The extent of tropical peats in Indonesia are estimated to be around 20 millions hectares, which store 50 to 57 Gt C (Jaenicke *et al*., 2008; Page, Rieley, and Banks 2011). Most of these peats have been disturbed, converted and drained for agricultural development. Peats belong to organic soils (Histosols), and store a large amount of organic carbon. Most of tropical peats in Indonesia are logged, drained and converted into agricultural uses. These disturbances are detrimental, as tropical peats become sources of CO_2 emission to atmosphere, and substantially reduce Carbon stock in tropical peats. This study aims to assess impacts of land uses on selected peat properties that control C stock in a disturbed and drained peat dome used for agriculture development.

STUDY SITE

This study site is located in Rasau Jaya peat dome, about 53,000 Ha, in West Kalimantan Province, Indonesia (See Figure 1). We recorded that human disturbances on this peat dome firstly occurred in 1970 in the form of timber harvesting. Then, the government of Indonesia drained and converted this peat into agriculture development in 1972. At that time, knowledge on tropical peats was very poor. Tropical peatlands were treated as a marginal land for agriculture. Drainage is common practice in order to lower water table and to enhance peat soil fertility.

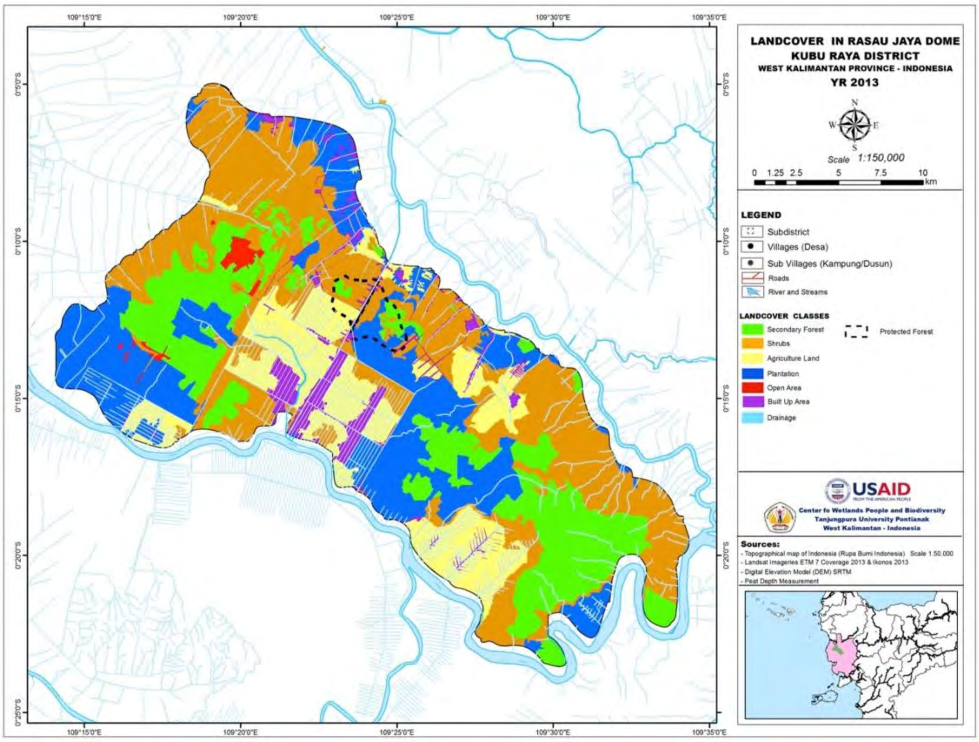

Figure 12: A map of Rasau Jaya peat dome, which is located in the upper Kapuas River of West Kalimantan Province, Indonesia

METHODS

We collected peat samples from two transects that cross over South to North, and East to West directions of Rasau Jaya peat dome. We investigated 22 peat core samples. We measured a total of 160 subsamples, consisting of 20 oil palms (OP), 57 degraded secondary forests (DF), and 83 open peats dominated by ferns (BF). We measured peat thickness with a Russian peat auger. Coring was done until reaching a mineral substratum. Samples were carefully collected for laboratory analyses. This fieldwork was done in five months, from September 2012 until February 2013. In addition, these subsamples were categorized into four thickness sections, consisting of surface tier (0-100 cm); sub-surface tier (100-200 cm); below tier (200-300 cm), and bottom tier (>300 cm). Research variables consist of bulk density (BD), total organic carbon (TOC), total nitrogen (TN), and organic matter content or loss on ignition (LOI). We also calculated C/N ratio, and carbon and nitrogen densities (CD and ND). BD is defined as a product of dry weight of peat samples (grams) by intact sample volume (cm^{-3}). CD and ND are products of BD ($g\ cm^{-3}$) multiplied by TOC (%) and TN (%), respectively.

LOI and BD were measured by gravimetric technique (Agus *et al*., 2011) (Anshari 2010; Anshari *et al.,* 2010) (Heiri, Lotter, and Lemcke 2001) TOC and TN were measured by high temperature combustion with CHNS analyzer (Anshari 2010; Anshari *et al*., 2010; Warren *et al*., 2012). We used one-way ANOVA and Games-Howell contrast comparisons to present and interpret research results.

RESULTS AND DISCUSSION

Table 1 shows that values of TOC, TN and LOI in oil palm are slightly lower than in open peat and degraded forest sites. CD and ND in oil palm are high due to high BD value. Low TOC and TN concentrations in OP suggest C loss due to decomposition. Decomposers use Nitrogen, which is also absorbed by plants when it is available on soils. TOC is converted into CO_2 gas, and other forms of soluble carbon compounds are dissolved in water. Low LOI strongly indicates C loss and high decomposition rate. High BD values on OP indicate peat compaction, consolidation, and shrinkage of organic particles. Based on ash content differences, it is estimated that percentages of chemical decomposition that leads to C emission are about 40%. It is assumed that all of ash contents are purely originated from the conversion of organic matters, and there is no external input of inorganic matters into the peats. Significant decomposition of carbon is detected by lowering TOC concentration and LOI, as shown on OP site.

Results of Levene tests on these variables, except CD, show that variances of all variables are highly significanty different. As expected, data distribution of these variables is not normal. Accordingly, Brown-Forsythe

ANOVA was applied rather than traditional ANOVA and identified significant differences of these variabel among peat thickness sections.

Table 3: Summary results of TOC, TN, C/N, BD, LOI, CD and TN on Oil Palm (OP), Open Peat (BF), and Degraded Secondary Forest (DF)

. Variables	OP (n=20)		BF (n=83)		DF (n=57)		Total (n=160)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TOC (%)	49.63	10.87	53.99	8.79	43.67	10.31	52.80	9.67
TN (%)	0.98	0.28	1.12	0.30	1.10	0.39	1.10	0.33
C/N Ratio	52.59	9.86	50.60	10.29	51.74	14.65	51.26	11.93
BD (g cm^{-3})	0.16	0.08	0.12	0.08	0.13	0.10	0.13	0.08
LOI (%)	86.37	16.18	92.41	15.15	90.26	17.22	90.72	16.10
CD (kg m^{-3})**	74.16	21.37	56.55	21.49	60.90	22.99	60.30	21.58
ND (kg m^{-3})*	1.50	0.74	1.14	0.42	1.22	0.50	1.22	0.51

Note: * and ** indicate landuse significantly affected variables at 0.05 and 0.01 level

It is important to note that mineralization or low content of organic matters on OP affect an increase of carbon density (CD) (See Table 2). An average value of ash free CD on OP must be lower than the present calculation, and is estimated to be about 64 kg m^{-3}.

Table 4: Results of Contrast Test for Carbon and Nitrogen Densities

Contrast	t-stat	df	p-value	t-crit
	Carbon Density (kg m^{-3})			
C1 (OP vs BF+DF)	3.07**	157	0.00	1.98
C2 (BF vs DF)	-1.20	157	0.23	1.98
	Nitrogen Density (kg m^{-3})			
C1 (OP vs BF+DF)	2.68**	157	0.01	1.98
C2 (BF vs DF)	-0.98	157	0.33	1.98

Note: ** indicate contrast is significant at 0.01 level

Table 2 presents a summary result of contrasts following thickness section groups. Generally, variables fluctuated at the upper thickness (< 200cm), and relatively constant at the bottom sections. Lower TOC and TN in the surface indicate decomposition rate of organic matter and mineralization occur more rapidly leading to carbon loss through emission and nitrogen loss through plants root retrieval. Further, decomposition and compaction due to physical disturbace increase BD in the suface.

Table 5: Summary results of TOC, TN, C/N, BD, LOI, CD and TN on thickness section group

No	Variables	Thickness Section Group									
		0-100 cm (n=15)		100-200 cm (n=25)		200-300 cm (n=40)		>300 cm (n=80)		Total (n=160)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	TOC (%)**	38.55	14.25	42.35	12.70	56.91	2.56	56.69	1.75	52.80	9.67
2	TN (%)**	0.83	0.42	0.81	0.42	1.08	0.22	1.25	0.22	1.10	0.33
3	C/N Ratio**	51.00	11.82	59.64	16.38	54.85	10.83	46.89	8.62	51.26	11.93
4	BD (g cm^{-3})**	0.25	0.12	0.22	0.10	0.10	0.03	0.09	0.03	0.13	0.08
5	LOI (%)**	68.66	22.29	77.55	18.14	97.36	3.88	98.18	6.43	90.72	16.10
6	CD (kg m^{-3})**	81.44	23.51	81.79	19.98	55.46	18.18	52.04	15.58	60.30	21.58
7	ND (kg m^{-3})**	1.72	0.84	1.47	0.54	1.05	0.43	1.13	0.35	1.22	0.51

Note: ** indicates peat thickness section significantly affected variables at 0.01 level

Table 3 presents that all of investigated peat properties are significantly differences following control sections of surface (0-100 cm), sub-surface (100-200 cm), below (200-300 cm) and bottom (> 300 cm) tiers. Values

of TOC and LOI in surface and sub-surface are lower than bottom and below tiers (Figure 2). In contrast, values of BD and TN are high and low in surface, respectively (See Figure 2).
Table 4 presents results of contrast tests on peat thickness sections. It shows that the surface and sub-surface tiers (Contrast D3) are all indifferent for all variables. However, combinations of the surface and sub-surface tiers contrasted to below tier (200-300 cm) show highly significant differences, except for C/N ratio (See Contrast D2). The combinations consisting of all tiers are all highly different from the bottom tier (Contrast D1). This analysis strongly pinpoints impacts of disturbances on tropical peats that cause substantial changes in surface peats, i.e., the surface tier (0-100 cm) and the sub-surface tier (100-1200 cm). Major changes in these tiers are lower values of TOC, TN and LOI, and substantial increases of BD in both surface and sub-surface than in the below and bottom thickness tiers (see Table 3 and Figure 2).

Table 6: Results of Contrast Tests on Peat Thickness Sections

No	Variables	Contrast		
		D1	D2	D3
		(0-100 + 100-200 + 200-300 cm) vs >300 cm	(0-100 + 100-200 cm) vs 200-300 cm	0-100 cm vs 100-200 cm
		q-stat		
1	TOC (%)	10.07** (q crit 1% = 4.825)	10.25** (q crit 1% = 4.818)	-1.20 (q crit 5% =3.870)
2	TN (%)	23.88** (q crit 1%= 4.624)	4.76** (q crit 1% = 4.666)	0.26 (q crit 5% = 3.854)
3	C/N Ratio	-6.27** (q crit 1% = 4.544)	-0.23 q crit 5% = 3.725)	-2.73 q crit 5% = 3.806)
4	BD (g cm^{-3})	-10.56** (q crit 1% = 4.797)	-9.89** (q crit 1% =4.798)	1.16 (q crit 5% = 3.881)
5	LOI (%)	9.67** (q crit 1% = 4.808)	9.64** (q crit 1% = 4.895)	-1.80 (q crit 5% = 3.917)
6	CD (kg m^{-3})	-7.12** (t crit 1% = 2.608)	-6.47** (t crit 1% = 2.608)	-0.06 (t crit 1% = 2.608)
7	ND (kg m^{-3})	-4.37* (q crit 5% = 3.811)	-5.56** (q crit 1% = 4.747)	1.48 (q crit 5% = 3.940)

a

b

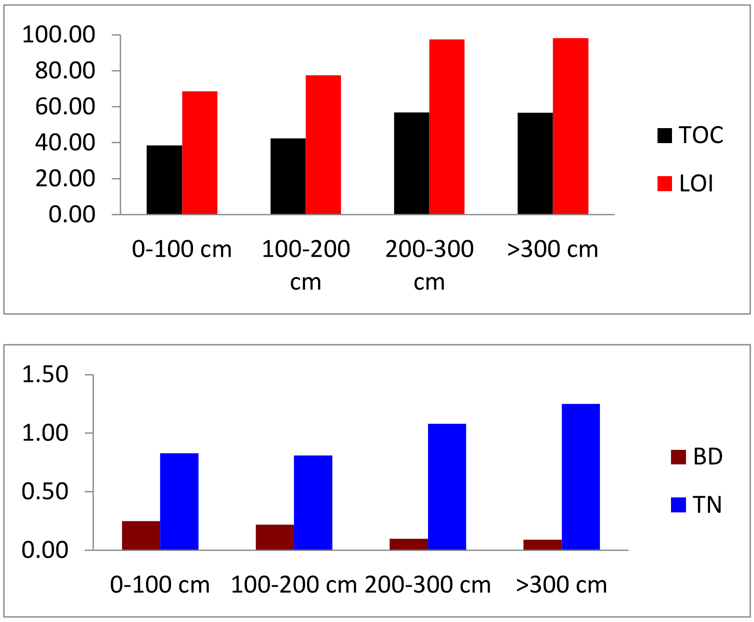

Figure 13: The average values of TOC and LOI (a); BD and TN (b) by peat thickness tiers

This study strongly shows that anthropogenic disturbances on tropical peats affect significant property changes on the upper section of peat thickness. This information is very important, as it will be useful for monitoring peat properties and carbon stock changes. It is also important to note that mineralization of peats would augment carbon stock due to an increase of bulk density, but significant reduction of total organic carbon.

CONCLUSION

This study highlights both natural and anthropogenic Carbon properties in tropical peats. Anthropogenic disturbances cause substantial changes of peat properties up to 200 cm thickness. This study concludes that monitoring Carbon stocks in disturbed and drained peats for agriculture must cover the upper 200 cm thickness. Bulk Density (BD) is the most important factor that control the amounts of C storage and emission

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