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OBSERVATIONS ON BIOMASS AND BIOGEOCHEMISTRY OF RAIN-FED PEAT DOME POLE FOREST, RIAU, SUMATRA

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SUMMARY

APRIL group operates a half million ha of fiber plantation and restoration concessions on coastal peatland in Riau. Half the area has been permanently set aside for nature, including extensive areas of pristine peat dome pole forest (PDPF) that grows on the raised surface of large ground-water domes. Permanent sample plots (PSP) established in PDPF have gained 16-32% in basal area (BA) since 2008, raising a question of where in a rain-fed organic landscape the minerals for biomass expansion have come from. Physical and chemical analysis indicates that mineral stores in the peat topsoil are relatively small while litter stores are more substantial. Rain while quite clean is abundant; quantities of cations sampled in rainfall appear to be adequate to have supplied the observed expansion of biomass. Soil drainage and subsidence may have stimulated biomass growth of one fastest grown PSP but not of a second one. Other potential sources of nutrient are air borne particulate haze that reaches nuisance levels each dry season, and guano from roosting fruit bats. Historical disturbance and subsequent recovery of PDPF cannot be ruled out. If biomass expansion on extensive ground water domes of Kampar is taking place it could prove important for biomass carbon capture and storage.

***Keywords**: peat dome pole forest, ground water dome, rain fed, geochemical inputs, basal area, canopy expansion*

INTRODUCTION TO STUDY AREA

A feature of the peat landscape of coastal Riau is the sight of extensive areas of stunted pole forest or semi-open ‗padang' scrub, growing on the raised surface of large ground water domes. A peat dome pole forest (PDPF) dome can be 30 km plus diameter with the ground surface elevated 10 m plus above mean sea level. Pole forest grows to about 20 m tall and Padang to half that. The short stature of vegetation is widely attributed to a limited supply of nutrient for a raised, convex landform that is free from groundwater geochemical (Brady, 1991). Nutrient inputs are limited to atmospheric sources like rain and dust. Nutrient scarcity pushes the vegetation to invest in roots for more thorough scavenging of nutrients, in turn feeding peat deposition and dome growth, until some limit is reached (Whitten, 1987). However, little experimental data from tropical peat domes has been gathered, in part due to difficulty of access to vast tracts of dense vegetation.

The study area is sited on the periphery of a large raised dome located on the Kampar Peninsular, 30 km from the coast (Figure 1). Like nearly all PDPF within APRIL concessions, it has been permanently set aside from development to provide services of nature. Beyond the natural forest, at lower elevation, is Acacia fiber plantation growing on peat. The local hydrology looks to be influenced by the large ground water dome. During the El Nino of 2015, the water table (WT) was of near uniform depth across this landscape extending from 2 km inside the pole forest until 2 km inside the plantation.

METHODS

The PDPF composition, structure and growth have been monitored periodically from 2008 until 2015 with 2 permanent sample plots (PSP) located in the study area (Figure 1). Additionally, soil subsidence and water table depth have been measured quarterly since August 2007 starting two months after PVC dip-well poles were installed. There is a pole at each PSP plus 5 more spaced between them and a final one located 400 m beyond PSP 2. In 2007 the peat depth was 11.5 m at both sites; PSP 1 was elevated at 12.3 m and PSP 2 at 13.0 m AMSL. Each PSP is 100 x 20 m in size. Trees 10.0 cm and larger in DBH were numbered with alloy tree tags in 2008, and in 2015 additional trees that had acquired 10.0 cm DBH were also tagged. These trees had DBH measured at 5 cm below the tag nail in 2008, 2011 and 2015. Tree tip height was also measured in 2015 on 10 trees per PSP of size that spanned the range of DBH.

Soil bulk density (BD) was sampled in 2015 at depths of 0-15, 15-30, 30-50, 50-75 and 75-100 cm using a cylindrical corer, replicated at 5 points within each PSP. Soil chemical analysis was done on a composite 0.5 kg sample aggregated from 5 separate locations from each depth within each PSP. Also in 2015, five 0.5 kg samples of fresh litter were taken from each PSP in order to determine chemical composition. To determine litter mass, five separate litter samples were taken each of 0.10 m^2 in area. No litter mass was sampled from the PSP prior to 2015, however in 2004 numerous samples of 0.10 m^2 area were taken from PDPF at similar elevation, 10-11 m AMSL, from another position on the same dome.

RESULTS

Since 2007the WT depth of PSP 1 has ranged from -54 cm to -86 cm; soil surface has subsided a mean of 4.6 cm p.a. PSP 2 WT has ranged +2 cm (flooded) to -54 cm; subsidence has been 0.0 cm. Soil and litter mass values, chemical content and that of rain and groundwater are summarized in Figure 2. There is no difference in BD with soil depth or between PSP; all samples measured 0.05 g /ml. Apart from PSP 2 having slightly lower Cu concentration than PSP 1, soil chemical values of the two PSP soils were similar as was vegetation composition. Litter samples averaged 240 g oven dry (OD) per 0.10 m^2 for PSP 1 and 370 g per 0.10 m^2 for PSP 2, with no chemical differences between them. Litter sampled during landscape survey in 2004 from a similar elevation to the study site averaged 200-250 g per 0.10 m^2 area. This observation suggests that PDPF litter tends to be uniform in mass and so is unlikely to have supplied nutrients to enable a rapid expansion of standing forest.

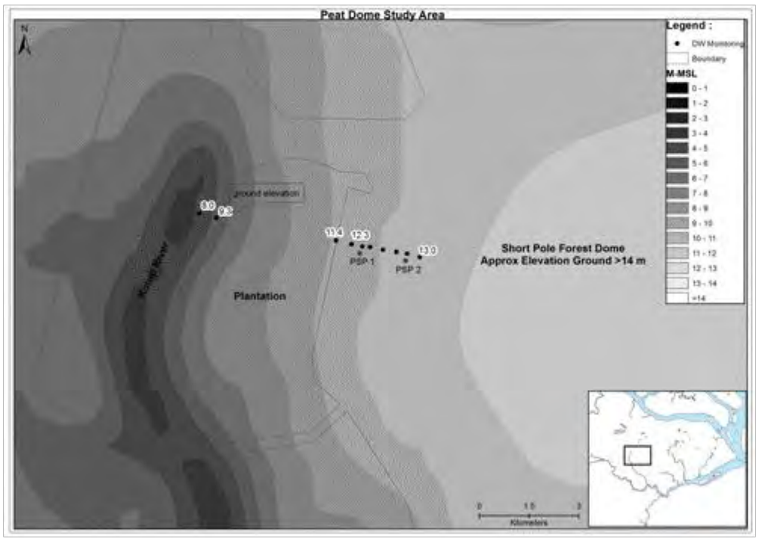

Figure 1: Study area location

PSP dominant tree species and their DBH increments are summarized in Figure 3. A marginal difference in mean DBH between the two PSP may be due to a wind toppled slight gap in PSP 2 having become surrounded by slightly fatter trees. DBH increment for all trees has averaged 0.4 cm p.a. at PSP 1 and 0.2 cm p.a. at PSP 2. Tree tip heights are given in Figure 4. The tree canopy of both PSP is near uniform in height and closure; it conforms to a single-tier model.

Total stem density and basal area by species of each PSP are summarized in Figure 4. In 2007 PSP 1 had 232 trees; in 2015 30 trees had grown in to the 10.0 cm minimum DBH size and 11 original trees had died. Corresponding numbers for PSP 2 are 206, 39 and 20.

The PSP each have 31 identified species; *Calophyllum ferrugineum, Sgzygium ochneocarpum, Campnosperma coriaceae* and *Shorea teysmanniana* are the most abundant trees in both PSP. A slight difference is that in PSP 1 these four trees contribute less to total BA, i.e. species diversity is better spread in PSP 1 (Figure 5). Stand BA has been taken as an index of biomass. There was a procedural issue that some trees in 2008 were estimated to be <10.0 cm DBH rather than measured; had they been >10.0 cm but not tagged in 2008 then stand growth 2008-16 would have been overestimated. Accordingly two estimates of 2008-2015 stand increment have been made; to include and to exclude stems that grew in to the >10.0 cm DBH threshold. Of the two the more conservative estimate of increment has been used in the concluding discussion.

To investigate nutrient inputs in rain, rainfall samples were collected following a published standard, 6 weekly between November 2015 and April 2016, at a canopy opening that occurs 200 m from PSP 1. Rainfall chemistry is included in Figure 2. While clean, rain does contain cations and N possibly in sufficient concentration such that the 2,400 mm p.a. rainfall may have supplied the theoretical quantity required for stand growth.

Water	Water Samples (concentration : mg / L)															
pH	EC	P	k	Ca	Mg	S	B	Cu	Fe	Mn	Na	Zn	Al		date	sample
4.2	24.0	0.25	4.35	0.59	0.11	0.99	<0.02	<0.01	<0.04	0.03	0.54	<0.01	<0.07		Nov-15	rain
4.3	18.7	0.05	0.09	0.11	<0.07	1.11	<0.02	<0.01	<0.04	<0.01	<0.01	<0.01	<0.07		Dec-15	rain
4.2	25.0	< 0.03		0.54	0.16	1.09	< 0.02	< 0.01	0.02	0.01	0.60	< 0.01	<0.07		Mar-16	rain
4.60	18.40	<0.03	0.05	0.08	0.04	0.85	0.01	0.005	0.02	0.01	0.55	0.02	0.85		Feb-16	rain
3.6	80.0	<0.03		<0.08	<0.07	0.58	<0.02	<0.01	<0.03	0.02	0.81	0.01	<0.07		Feb-16	ground
3.5	84.0	< 0.04		0.13	0.05	0.24	< 0.03	< 0.02	0.11	0.00	1.73	< 0.02	<0.08		Mar-16	ground
layer	N-kjel	Soil Samples (concentration : mg / L)												bulk density		
0-15 cm	8.62	17.8	25.5	62.4	49.0	13.4	0.09	0.07	3.59	0.63	1.46	0.53		0.050	Sep-15	PSP 1
15-30 cm	8.33	12.1	18.7	38.6	41.1	11.1	0.05	0.05	3.64	0.38	1.98	0.36		0.050	Sep-15	PSP 1
30-50 cm	5.16	4.9	7.1	27.9	16.4	4.3	0.04	0.05	4.69	0.18	1.07	0.28		0.050	Sep-15	PSP 1
50-75 cm	13.46	7.8	13.8	51.2	24.2	6.7	0.02	0.05	1.25	0.28	2.3	0.70		0.053	Sep-15	PSP 1
75-100 cm	11.05	8.0	15.1	32.0	22.1	8.8	0.05	0.03	7.69	0.46	1.9	0.55		0.054	Sep-15	PSP 1
0-15 cm	6.55	14.5	44.3	211.9	43.6	13.8	0.24	0.05	11.58	1.60	2.61	0.51		0.050	Oct-15	PSP 2
15-30 cm	6.58	12.1	36.0	57.4	39.1	15.9	0.13	0.04	12.80	0.57	2.08	0.34		0.054	Oct-15	PSP 2
30-50 cm	4.11	8.1	25.3	29.5	26.1	10.2	0.10	0.04	9.88	0.05	1.58	0.29		0.054	Oct-15	PSP 2
	N-kjel	Litter layer Samples (concentration : mg / L)												mass g /0.1 m2		
	0.56	0.00	0.04	0.06	0.02	0.01	1.91	0.05	2.66	7.63	5.33	1.06	126.93	240	Oct-15	PSP 1
	2.24	0.04	0.35	1.76	0.29	0.09	21.25	0.42	65.63	181.06	93.15	13.06	64.40	370	Nov-15	PSP 2

Figure 2: Chemical analyses of Soil, Litter, Water

	PSP 1		PSP 2	
Dominant Tree Species	2008 BA m2/ha	mean DBH gro cm p.a.	2008 BA m2/ha	mean DBH gro cm p.a.
Shorea uliginosa	0.95	0.50	0.01	0.50
Ormosia sumatrana	0.95	0.51	1.50	0.35
Campnosperma coriaceae	3.15	0.55	1.80	0.22
Shorea teysmanniana	0.50	0.67	5.60	0.32
Calophyllum ferrugineum	4.05	0.58	4.10	0.27
Mangifera cf. havilandii	1.15	0.00	0.03	0.10
Syzygium sp.	1.85	0.19	0.05	0.00
Stemonurus secundiflorus	0.50	0.09	-	-
Tetramerista glabra	2.00	0.06	1.30	0.10
Knema sp.	0.25	0.05	0.15	0.16
Garcinia eugeniifolia	0.60	0.03	0.50	0.02
Combretocarpus rotundatus	0.40	0.05	0.60	0.21
BA of 12 dominant sp.	**16.35**	**0.36**	**15.64**	**0.23**

Figure 3: Dominant Spp. basal area & DBH increment

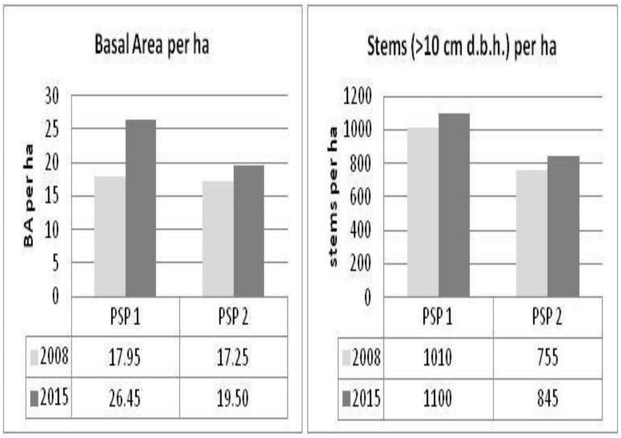

Figure 4: Basal Area and Density of PSP

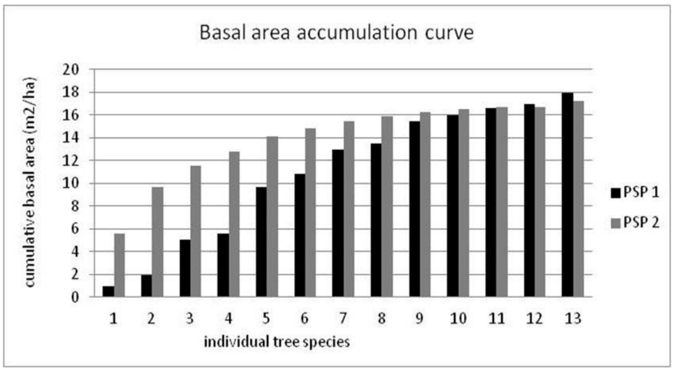

Figure 5: Cumulative Basal Area as index of diversity

CONCLUDING DISCUSSION

Taking a conservative approach that excludes trees grown into the >10.0 cm BDH class trees subsequent to 2007 measurement, PSP 2 gained 16% BA while PSP 1 has gained 32% BA, over the 7.1 year interval. Such a large increment for PSP 1 raises a question of from where came the scarce Ca, k, Mg and other cations required for this magnitude of biomass expansion.

Figure 2 includes indicative values for soil cations contained in the upper 1 m of the soil profile. Cation concentrations are higher in soil layers above 30 cm depth than they are below 30 cm deep. This is consistent with cation supply being added to the soil profile from above, via leaf and litter fall, or from canopy and stem flow, i.e. being rain fed, while being leached from the deeper soil profile by water movement. At both PSP a thick dense mat of live roots separates the surface litter layer from the peat deposit below. The latter is comprised of dead roots, as per observation by Brady (1997). PSP 1 stand has achieved twice the increment as PSP 2 stand, despite both stands growing on soil containing the similar concentration and total quantity of soil cations. This suggests a dominant source for cation supply may not depend on the soil.

PSP 1 total biomass is estimated to be around 100 T /ha; Siregar *et al* (2012) found that *Acacia* plantation on peat soil, similar in total biomass to our current study, contained 68 kg /ha of minerals. Indicatively, a 3% p.a. expansion of that vegetation would require 2 kg / ha p.a. of minerals. The product of soil chemical concentration and subsidence rate in the PDPF are quite inadequate to have supplied that amount. Chuyong *et al* (2002) found that rainfall supplied the majority of minerals, including K, for central African rainforest. Likens *et al* reported that rainfall supplied up to 20 kg / ha p.a. of nutrients to tropical forest systems. While biomass analysis and ground water chemistry study is required to be certain, indications are that PDPF biomass gain reported here could have been sustained by rain fed inputs of minerals.

Another source of minerals may be dry deposition of dust and ash from seasonal biomass burning (Lieu, 2014). Slash and burn local agriculture is common practice in the region, e.g. in vicinity of Kampar River 25 km away. Another potential input is mineral rich bat guano. Large colonies have been observed roosting in *Bintangur* dome forests of offshore islands, and clumps of a few pole trees damaged apparently by roosting bats have been noted in the study area dome. Gumal (2004) describes large colonies of Malaysian fruit bats that favor and reuse many times certain roost trees. Finally, the drainage and subsidence measured at PSP 1 could have contributed to mobilizing nutrients from surface stores in the dome soil and may help account for the greater stand increment at this slightly modified site.

Importantly, if the magnitude of stand increment measured at PSP 2 can be confirmed, biomass stores of Kampar landscape may be accumulating atmospheric CO_2 at a significant rate. There are some half million ha of PDPF on the Kampar; a 10% increase in biomass per decade might capture in the order of one million T of CO_2 p.a.

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