J. Trop. Agric. and Fd. Sc. 33(2)(2005): 293–302

Quantification of woody biomass after clearing of peat forest

(Kuantifikasi biomas kayu-kayan selepas pembukaan hutan gambut)

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Key words: peat, land clearing, woody biomass, tropical, swamp

Abstract

A study to quantify the amount of woody biomass present above and below ground surface immediately after clearing of a peat swamp forest was carried out at MARDI Peat Research Station, Sessang, Sarawak. The area had been partially drained for more than five years and had previously been heavily logged. 'Slash-and-stack' method of land clearing had left behind about 2,277 m^3/ha of forest debris, occupying 13–17% of the cleared area. The volume of the woody debris with a diameter larger than 1.5 cm was about 169 m^3/ha, with an estimated weight of about 123 x 10^3 kg/ha. More than half of the woody debris was of diameter less than 15 cm. Below the surface, the woody biomass increased with depth, ranging from 7–20% of the soil volume, with an overall volume of about 15% in the top one meter. The bulk of the debris was of diameter 2.5–15 cm.

Introduction

Approximately 2.6 million ha of peat land exist in Malaysia, accounting for about 8% of the total land area. Of this, 1.66 million ha is found in Sarawak, 0.8 million ha in Peninsular Malaysia and 86,000 ha in Sabah (Mutalib et al. 1992). Economic and social developments had increased the demand for land, resulting in the populace having to encroach into peat swamp areas. Currently, more than 360,000 ha of peat land in the country has been developed, mainly for agriculture. With improved knowledge and the development of new technologies, more intensive or large-scale agricultural activities on peat are made possible.

As in many other areas, the development of peat land involves land clearing, which is commonly by 'slash-and-burn' method. Peat, being organic in nature, is easily burnt, particularly during dry weather and with a deep water table. Under controlled water table conditions, the 'slash-and-burn' land clearing method at the MARDI Peat Research Station in Sessang, Sarawak, for example, had resulted in surface subsidence of 38 cm, of which about 10 cm could be attributed to the burning of the top soil (Jamaluddin 2003).

The practice of burning also contributes significantly to air pollution, which on a large scale can result in a severe haze problem over a large area. In addition, burning of peat also releases more than 80 gaseous compounds, some of which such as aliphatic and aromatic hydrocarbons are toxic, furfurals and organic acids containing cancer-causing substances (Okazaki et al. 1999). Information on the amount of biomass from clearing of peat swamp forest, including the extent of potential hazards from its burning is lacking.

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Moore and Haase (2003) estimated that the 1997/98 Indonesian peat fires released carbon equivalent to 13–40% of the annual emission caused by burning of fossil fuels around the world. This was a significant additional pollutant to the annual CO_2 fluxes of about 27 t/ha/year from the decomposition of peat after land clearing and agricultural development (Wosten et al. 1997). Burning of the debris will also immediately release some nutrients, which will be lost from the system through drainage and waterways (Janice et al. 2003).

To avoid these potential hazards, zero-burning land clearing method is generally recommended and is currently practised by some plantations. This method leaves behind a large amount of woody debris, which occupies the potential cultivable area. For cultivation of annual crops, the debris needs to be stacked at selected locations in order to maximise planting space. Whereas for perennial crops, planting can be done in between the debris stacking rows, without having any effect on planting density. Inadequate information on the magnitude of biomass from clearing of peat forest limits the capacity to estimate the potential area for crop cultivation.

Peat also contains large amount of semi-decomposed woody materials below the surface, which pose serious problems for farm mechanization. It had been reported that these materials occupied up to 50% of the soil volume (Coulter 1950). Comprehensive information on this subject is deficient. As such, a study was carried out with the main objective of quantifying the magnitude and nature of the woody debris present above and below the soil surface immediately after clearing of peat forest. The information gathered will be useful in decision-making and land-use planning.

Materials and methods

Study site

The study was carried out at MARDI Peat Research Station, Sessang, Sarawak. The whole Station was located over 387 ha of peat forest that ranged from 0.5 m to more than 5 m deep (Anon. 1996). Though the forest had previously been intensively logged, a preliminary study indicated that the plant diversity in the area was fairly high, with 148 species representing 66 families and 91 genera (Salma et al. 2003). The most common top-level tree species identified was *Macaranga* spp. (mahang), reaching the height of 20–25 m. The sub-tree layer, standing between 10 m and 20 m, consisted of common species such as *Blumeodendron tukhbrai* (merbulan), *Eugenia* spp. (kelat), *Diospyros* spp. (kayu arang), *Litsea* spp. (medang), *Pometia pinnata* (kasai) and *Xylopia corrifolia* (jangkang paya). Other than these, there were many other species of shrubs and herbs. The area had been partially drained since early 1990s with some drains having been constructed in the adjacent plot where oil palms were planted.

Quantification of above ground biomass

The study was confined to a 23-ha plot where the ‘slash-and-stack’ method of land clearing was employed. The felled trees and the debris were stacked in rows and left to rot. Quantification of the above ground forest debris was carried out from the stacks. The number of stacks was counted and their lengths were measured. The height and top and bottom widths of the stacks were measured at random. Due to their almost uniform cross-sectional area, only five stacks were randomly selected for a detailed study. Each selected stack was subjected to three sampling points, located about 5 m, 30 m and 50 m from one end. At each of these points, woody debris was extracted from between two cuts, one meter apart and perpendicular to the length of the stack. The debris was then separated into four size groups, that is 1.5–2.5 cm, 2.5–15 cm, 15–30 cm, and >30 cm in diameter. The samples were weighed and the volume was gauged by water displacement.

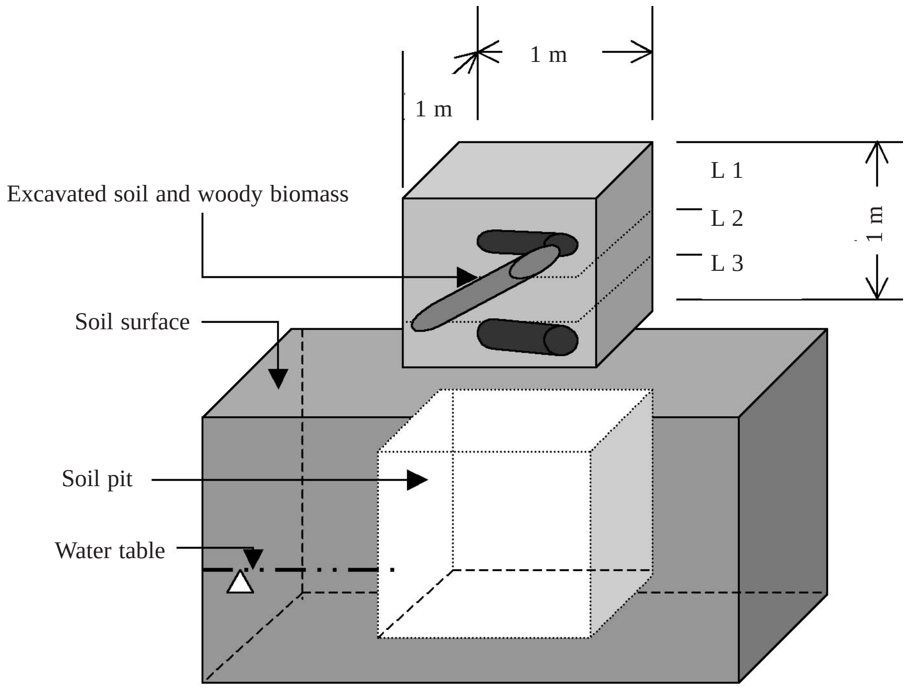

Figure 1. Underground sampling of woody biomass

Quantification of underground biomass

Quantification of sub-surface woody material was carried out from six soil pits measuring 1 m^3 each *(Figure 1)* located randomly in the 23 ha plot. A chainsaw was used to incise the soil and cut the buried wood debris. In order to facilitate the work, the debris had to be severed into smaller pieces before they were excavated. The debris was categorized into three groups according to the depth at which they were extracted, distinctively 0–33 cm (L1), 33–66 cm (L2) and 66–100 cm (L3). Subsequently, the samples were separated into four size groups as in the study of the above ground materials. Similarly, the samples were weighed and volume was gauged by water displacement.

Results and discussion

Above ground biomass

Measured dimensions of the stacks are shown in *Table 1* and *Appendix 1a*. Based on the measurements, estimated total stacking area for all the rows was 38,800 m^2 which was equivalent to 1,687 m^2/ha or about 17% of the cleared area. This type of stacking rows is more suitable for planting of perennial crops, such as oil palm and sago which require less movement of personnel and larger distance between plants and inter-row spacing. Whereas for annual crops, the stack needs to be placed in one location in order to maximize planting area. Under this condition, based on volume and height and assuming that the stacks were uniform, it was calculated that the required stacking area was about 1,265 m^2/ha, or

Table 1. Stacking dimension of forest debris immediately after clearing

Stacking parameters		Dimension
Cleared area		23 ha
Number of stack		31
Total length of stack		9,700 m
Average length of stack		312.87 (46.31)
Estimated top width of stack		2 m (0.61)
Average bottom width of stack		4 m (1.31)
Average height of stack		1.85 m (0.3)
Stacking area (calculated)		38,800 m^2
Stacking area per ha (calculated)		1,687 m^2
Stacking volume	calculated after assuming that the	52,380 m^3
Stacking volume per ha	stacks are trapezoid in shape	2,277 m^3/ha

Parenthesized values represent Standard Deviations

Table 2. Measured and calculated weight and volume of the woody biomass above the surface

Size of debris (diameter in cm)	Weight (kg)		Volume (m^3)	
	Per sampling area* (averaged)	Per ha** (calculated)	Per sampling area* (averaged)	Per ha** (calculated)
1.5–2.5	27.67 (14.51)	11,690	0.04 (0.02)	17
2.5–15	135.55 (49.16)	57,181	0.18 (0.07)	76
15–30	59.43 (46.23)	25,067	0.10 (0.08)	42
>30	70.07 (95.97)	29,582	0.08 (0.10)	34
Total	292.72	123,520	0.40	169

Parenthesized values represent Standard Deviations
*Sampling area = 1 m of the stack
**1 ha = 422 m of stack (i.e. 9,700 m^2/23 m)

Table 3. Measured and calculated weight and volume of biomass below the surface (average per soil pit)

Depth level	Size groups of the debris (diameter in cm)				Total
	1.5–2.5	2.5–15	15–30	>30	
	Weight (kg)				
L1 (0–33 cm)	0.0	19.08 (14.86)	3.33 (7.45)	0.0	22.42 (15.89)
L2 (33–66 cm)	0.0	37.25 (12.47)	17.50 (19.54)	0.0	54.75 (19.63)
L3 (66–100 cm)	0.0	42.33 (25.07)	18.08 (29.19)	7.42 (16.58)	67.83 (49.17)
Total	0.0	98.66	38.91	7.42	145.00
	Volume (m^3)				
L1 (0–33 cm)	0.0	0.02 (* 6%)	0.01 (*1.5%)	0.0	0.03 (7.5%)
L2 (33–66 cm)	0.0	0.04 (*10%)	0.01 (*4%)	0.0	0.05 (14.5%)
L3 (66–100 cm)	0.0	0.04 (*12%)	0.02 (*5%)	0.01 (*2%)	0.07 (20%)
Total	0.0	0.10 (10%)	0.04 (4%)	0.007 (1%)	0.15 (15%)

Parenthesized values represent Standard Deviations
(*Percentage from 6 pits)

13% of the cleared area. This approach can be expected to be more costly, as it will consume more time, energy and fuel to move the debris over longer distances.

Table 2 and *Appendix 1b* show that the average volume of woody biomass from a sampling point was about 0.4 m^3. This corresponded to about 169 m^3/ha or merely 7% of the total stack volume indicating that the bulk of the stack consisted of empty spaces or voids. It was also apparent that about 55% of the debris was found to be less than 15 cm in diameter.

The high percentage of voids or empty spaces within the stack, as well as large amount of small size debris, suggest possibility of lessening the stack volume and extent with appropriate management of the debris. This can possibly be accomplished through mechanical compaction or reduction of the debris size by chipping prior to stacking. However, these practices are expected to be less practical due to marginal improvement against substantially higher cost. A better alternative is to leave the stack to naturally decompose in the field. The smaller size debris, 1.5–15 cm diameter, which amounted to 55% of the volume can be expected to decompose fairly fast, probably within two to three years. Coupled with enormous voids, this could result in natural crumbling of the stack due to the load exerted by larger size debris, which would subsequently reduce the stack volume. The process will continue but can be expected to slow down at the later stages as the residual debris are more resilient to degradation.

Table 2 also shows that the calculated weight of the biomass with a diameter larger than 1.5 cm was more than 0.123 x 10^6 kg/ha. Assuming the average water content of the biomass was about 20%, as the sampling and measurement was carried out about six months after felling, the dry weight of the biomass is estimated to be about 0.1 x 10^6 kg/ha. Burning of the debris will result in significant release of smog, carbon dioxide and other gases into the atmosphere.

Underground biomass

The average weight and volume of underground woody biomass from the pits are shown in *Table 3* and *Appendices 2a* and *2b*. The amount of biomass, in terms of weight and volume was greater at the lower depths, most being in the 2.5–15 cm size group. The lower amount at shallow depth could be due to higher rate of decomposition near the surface due to drier state as the area had been partially drained since early 1990s (Anon. 1996). At the lower depth the biomass was moderately preserved under waterlogged conditions of the peat environment. It is also interesting to note the comparatively much higher volume of underground biomass to that of above ground with the values of 250–650 m^3/ha and 169 m^3/ha respectively. The measured volume of 7–20% was found to be much less than the 50% reported by Coulter (1950). The dissimilarity could be the result of different approach to the study, different methods of measurements and interpretations.

Conclusion

This study provides some realistic and useful information for determination of suitable methods in clearing of peat-land and management of the forest debris. The information on the total biomass can give quantitative indication on the potential effect of burning to CO_2 emission. Land clearing by zero burning land which employs 'slash-and-stack' method is suitable for cultivation of perennial crops. Initial high volume of the forest debris is manageable and expected to decrease fairly fast. Immediate and rapid decomposition of small size debris, which account for more than 50% of the volume, is expected to cause the stack to crumble under its own weight, because of enormous amount of voids and empty spaces. Knowledge on the composition and nature of the underground biomass would facilitate efforts towards introducing suitable mechanization approaches. Continuous monitoring of the decomposition of the forest debris within the stacks and below the soil surface needs to be carried out to establish a comprehensive set of scientific data on the cycle from felling to total degradation.

Acknowledgement

This project was funded by MARDI under the RM 8 R&D project (Project No. 75). The authors wish to express their gratitude to the management of MARDI Peat Research Station, Sessang, Sarawak, for the support and facilities rendered. Special thanks are due to Mr Bolhassan Pawi for his hard work in accomplishing the data collection. Special acknowledgments are also due to Dr Mohamad Hanif Jamil, Mr Kamarudin Ambak and Dr Rezuwan Kamaruddin for their comments on the manuscript

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Abstrak
Kajian untuk menentukan status kayu-kayan di atas dan di bawah permukaan tanah sejurus selepas pembukaan kawasan gambut telah dijalankan di Stesen Penyelidikan Tanah Gambut MARDI, Sessang, Sarawak. Kawasan ini telah dibalak dan disalirkan selama lebih daripada lima tahun. Pembersihan hutan secara 'tebang-dan-timbun' (slash-and-stack) telah meninggalkan longgokan sisa hutan sebanyak 2,277 m^3/ha dan memerlukan ruang sebanyak 13–17%. Jumlah kayu-kayan sisa hutan yang bergaris pusat melebihi 1.5 cm adalah kira-kira 169 m^3/ha, dengan beratnya 123 x 10^3 kg/ha, dan lebih daripada separuh bergaris pusat kurang daripada 15 cm. Isi padu kayu-kayan di bawah permukaan tanah bertambah dengan kedalaman, di sekitar 7–20% daripada isi padu tanah, dengan purata 15% sehingga kedalaman satu meter, dan sebahagian besarnya bergaris pusat 2.5–15 cm.

Accepted for publication on 25 February 2005

Appendix 1a. Stack size

Stack No.	Length (m)	Bottom width (m)	Top width (m)	Height (m)
1**	341.0	4.2	2.6	2.0
2	345.0	4.5		2.2
3**	341.0	4.0	1.8	2.0
4	340.0	5.0		1.6
5**	344.0	5.5	2.3	2.0
6	342.0	5.7		1.8
7**	345.0	8.0	3.5	2.3
8	345.0	4.0		1.7
9	340.0	2.7		1.5
10**	338.0	5.5	2.5	2.2
11	343.0	5.4		2.2
12	345.0	4.0		1.5
13	343.0	4.5		1.5
14	344.0	3.0		1.5
15*	342.0	3.5	1.8	2.3
16	344.0	3.3		2.0
17*	341.0	3.6	1.8	2.0
18*	342.0	4.0	2.0	1.3
19	342.0	4.0		1.7
20	120.0	4.5		2.5
21	281.0	2.0		1.5
22*	280.0	3.5	1.8	1.5
23	278.0	2.0		1.5
24**	274.0	2.0	1.0	1.8
25	282.0	4.0		1.6
26*	271.0	3.0	1.5	2.0
27	282.0	3.0		1.5
28	280.0	2.0		2.0
29	280.0	3.5		2.0
30	282.0	6.0		2.0
31*	282.0	4.0	1.8	2.0
n	31	31	12	31
Total	9699.00	123.90	24.30	57.20
Mean	312.87	4.00	2.03	1.85
Sd	46.31	1.31	0.61	0.30

*and ** = Sampled stacks

Appendix 1b. Sample weight and volume of above ground biomass

Sample No.	Sub-Samp. Nos.	Debris Size <2.5 cm		2.5–15 cm		15–30 cm		>30 cm		Total	
		Wt (kg)	Vol (m^3)	Wt (kg)	Vol (m^3)	Wt (kg)	Vol (m^3)	Wt (kg)	Vol (m^3)	Wt (kg)	Vol (m^3)
1	1	36.00	0.04	116.00	0.17	181.50	0.35	46.00	0.06	379.50	0.61
	2	43.00	0.06	238.00	0.33	66.00	0.13	29.00	0.07	376.00	0.59
	3	21.00	0.05	93.50	0.15	35.00	0.06	0.00	0.00	149.50	0.25
2	1	12.00	0.02	65.00	0.10	72.00	0.12	73.00	0.12	222.00	0.38
	2	24.50	0.03	172.50	0.22	62.00	0.08	196.00	0.18	455.00	0.51
	3	25.00	0.03	136.50	0.16	30.50	0.03	0.00	0.00	192.00	0.22
3	1	18.50	0.03	85.00	0.12	146.50	0.22	105.00	0.12	355.00	0.49
	2	66.00	0.09	200.50	0.27	51.00	0.07	0.00	0.00	317.50	0.43
	3	5.50	0.01	96.50	0.11	48.00	0.05	374.50	0.40	524.50	0.57
4	1	40.00	0.06	166.50	0.24	74.00	0.10	0.00	0.00	280.50	0.40
	2	17.00	0.03	73.50	0.10	22.00	0.04	70.00	0.07	182.50	0.24
	3	19.50	0.03	174.00	0.26	37.00	0.14	66.50	0.08	297.00	0.51
5	1	19.50	0.03	125.00	0.21	51.50	0.09	32.00	0.07	228.00	0.40
	2	30.00	0.04	179.50	0.26	14.50	0.03	59.00	0.06	283.00	0.38
	3	37.50	0.05	110.50	0.16	0.00	0.00	0.00	0.00	148.00	0.21
Total		415.00	0.60	2032.50	2.85	891.50	1.50	1051.00	1.23	4390.00	6.18
Mean		27.67	0.04	135.50	0.19	59.43	0.10	70.07	0.08	292.67	0.41
Sd		14.51	0.02	49.16	0.07	46.23	0.08	95.97	0.10	107.15	0.13

Appendix 2a. Weight of biomass below ground according to depth

Sample No.	Level									Total
	1 (0–33 cm)			2 (33–66 cm)			3 (66–100 cm)			
	<1"	1–6"	6–12"	<1"	1–6"	6-12"	<1"	1–6"	6–12"	
1	0.00	6.50	0.00	0.00	40.50	0.00	0.00	18.00	0.00	65.00
2	0.00	0.00	0.00	0.00	37.50	31.50	0.00	52.50	81.00	202.50
3	0.00	15.50	0.00	0.00	21.00	0.00	0.00	90.50	44.50	171.50
4	0.00	15.50	20.00	0.00	50.00	0.00	0.00	36.50	0.00	122.00
5	0.00	39.00	0.00	0.00	21.50	51.50	0.00	41.00	22.00	175.00
6	0.00	38.50	0.00	0.00	53.00	22.00	0.00	15.50	5.50	134.50
Total	0.00	115.00	20.00	0.00	223.50	105.00	0.00	254.00	153.00	870.50
Mean	0.00	19.17	3.33	0.00	37.25	17.50	0.00	42.33	25.50	145.08
S.d	0.00	14.84	7.45	0.00	12.47	19.54	0.00	25.07	29.31	44.62

Appendix 2b. Volume of biomass below ground according to depth

Sample No.	Level									Total
	1 (0–33 cm)			2 (33–66 cm)			3 (66–100 cm)			
	<1"	1–6"	6–12"	<1"	1–6"	6–12"	<1"	1–6"	6-12"	
1	0.00	0.01	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.07
2	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.05	0.07	0.17
3	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.09	0.04	0.17
4	0.00	0.01	0.02	0.00	0.04	0.00	0.00	0.04	0.00	0.12
5	0.00	0.05	0.00	0.00	0.02	0.03	0.00	0.04	0.02	0.16
6	0.00	0.04	0.00	0.00	0.05	0.02	0.00	0.01	0.01	0.14
Total	0.00	0.12	0.02	0.00	0.21	0.08	0.00	0.24	0.14	0.82
Mean	0.00	0.02	0.00	0.00	0.04	0.01	0.00	0.04	0.02	0.14
S.d	0.00	0.02	0.01	0.00	0.01	0.01	0.00	0.02	0.02	0.04