3. Above-ground biomass

Figure 31 shows the average biomass according to culms development stage classes at 0-5 m for three bamboo species. The above-ground bamboo biomass comprises the culms, branches and leaves in relation to diameter at breast height were worked out. The result shows that total biomass increase variably with the diameter classes. The average biomass for three bamboo species indicates that each components of bamboo have different biomass values. *D. asper* shows the highest biomass of each component including the culms, branches and leaves with 1.32 kg, 0.68 kg and 0.41 kg respectively. The figure indicates that the culms of *D. asper* contain high biomass at 0-5 m the culms development stage classes.

The culms development stage classes at 5-10 m shown in Figure 32. *Bambusa bambos* shows the highest average biomass with 2.98 kg than the other bamboo species. Refering from the Figure 30, at the stage 5-10 m the average DBH of *B. bambos* culms were reached to 4.6 cm. This figure indicates that the increasing of DBH and height will influence the biomass value.

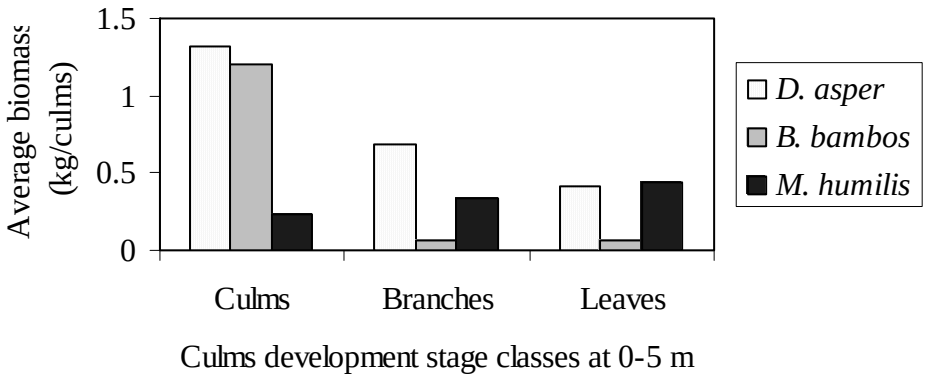

Figure 31 The average bamboo biomass according to culms development stage classes 0-5 m

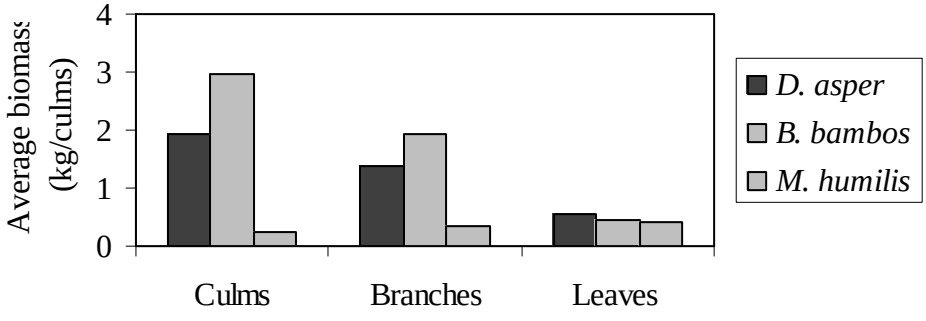

Figure 32 The average bamboo biomass according to culms development stage classes at 5-10 m

Figures 33 and 34 show the culms development stage classes at 10-15 m and 15-20 m. *D. asper* has the highest biomass according to two culms development stages classes at 10-15 m and 15-20 m with 48 kg and 14.41 kg respectively. According to Shanmughavel and Francis (2001), generally the total above ground biomass (dry matter) may be increased concomitant with DBH and height of the culms. The culms may contribute as major sharing to the increasing of total biomass.

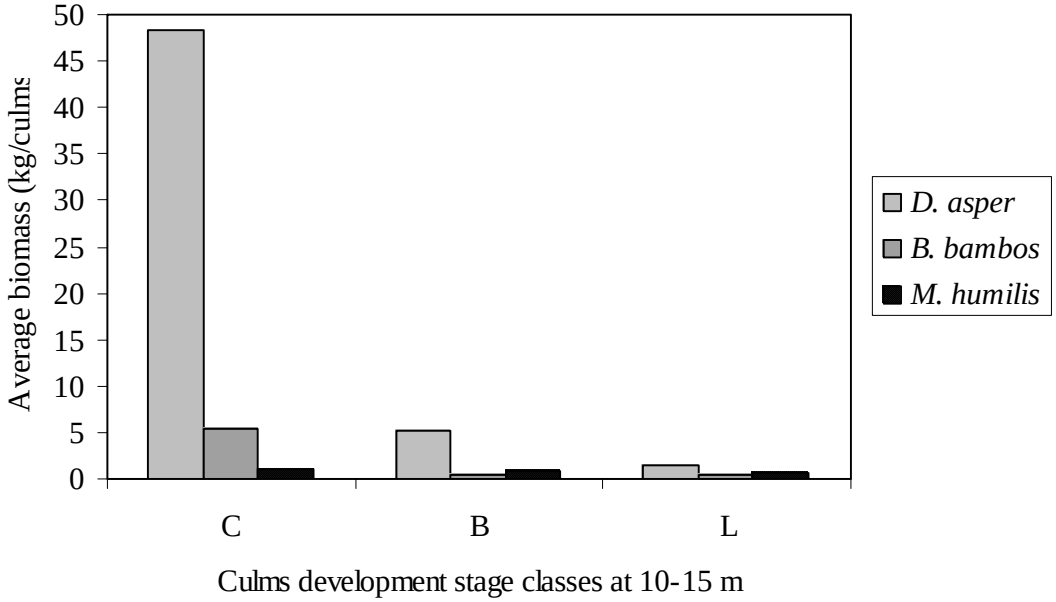

Figure 33 The average bamboo biomass according to culms development stage classes at 10-15 m

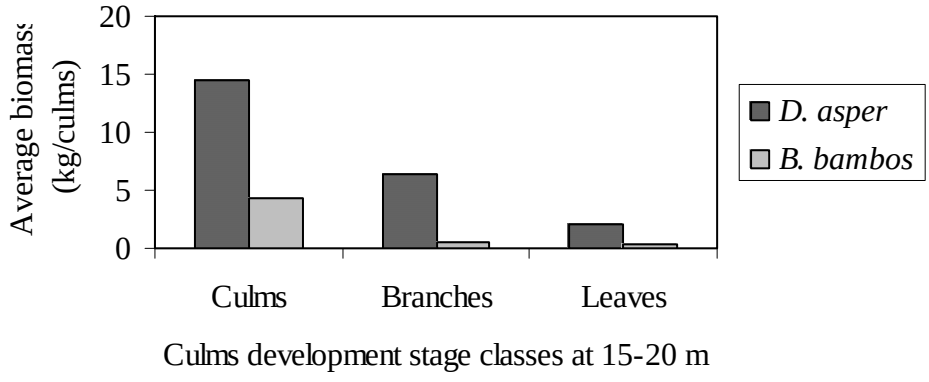

Figure 34 The average bamboo biomass according to culms development stage classes at 15-20 m

The results from Analysis of Variance in Table 46 indicates that the height percentage were significantly to total above-ground biomass at 0.05 levels, but among the culms DBH and bamboo species not significant. The percentage of height contributes the major increasing of total above-ground biomass. The relation between diameter and height were highly significant to the total above-ground biomass by the following linear regression equations at <0.01 (Othman, 1992).

Table 46 Analysis of Variance for culms average height

Sources of variation		df	SS	MS	F
Culms DBH	Between Groups	10	30.914	3.435	12.213^{ns}
	Within Groups	1	.281	.281	
	Total	10	31.195		
Total above-ground biomass	Between Groups	9	2507.749	278.639	244.118*
	Within Groups	1	1.141	1.141	
	Total	10	2508.891		
Bamboo species	Between Groups	9	4.909	.545	.273^{ns}
	Within Groups	1	2.000	2.000	
	Total	10	6.909		

* Significant difference at 0.05 level
^{ns} Non-significant at 0.05 level

The fresh and dry weight of culms, branches and leaves and total above-ground biomass of *D. asper* were shown in Tables 47 and 48. The weight of sample and total weight for both samples were recorded to calculate the total above-ground biomass. In that table, the total biomass for *D. asper* leaves increased to 2.104 kg/culms based on the culms development stage classes at 15-20 m. According to Shamughavel and Francis (2001), the entire biomass productivity may depend ultimately on the photosynthetic efficiency of the leaf. The square of diameter and height related with total biomass (Madgwick, 1971; Rai, 1984; and Othman, 1992). The total fresh weight of one culm of *D. asper* was influenced by the increasing of culm height. The fresh and dry weights of B. bambos were shown in the Tables 49 and 50. The highest biomass of *B. bambos* culms are in the culms stages classes at 10-15 m with 5.724 kg/culms with diameter 6.1 cm. In Tables 51 and 52, the fresh and dry weight for *M. humilis* is summarized with the total above-ground biomass analysis. The highest biomass of *M. humilis* indicates that at the culms stage classes 10-15 m with diameter 6.2 cm and 12 m height consists 1.332 kg/culm.

Figure 35 shows the regression relationship between culms development stage classes and total biomass in fresh and dry weight of *D. asper* which include culms,

branches and leaves. The figure indicates that the coefficients of both equations were significant at 86% and 81%. Figure 36 shows the regression relationship between culms development stage classes and total biomass in fresh and dry weight of *B. bambos.* The result shows that the equations of *B. bambos* different with the coefficient at 41% for the total fresh weight and 65% for the total dry weight. The differences show that at the stages 10-15 m and 15-20 m, the total biomass of *B. bambos* decreased. According to Othman (1992), the relationship between DBH and height will influenced the total fresh weight and total dry weight of culms, branches and leaves. Figure 37 shows the regression relationship between culms development stage classes and total biomass in fresh and dry weight of *M. humilis.* The figure indicates that the pattern of regeression between total fresh weight and total dry weight were different at 75% and 63% respectively. At the mature culms development stages classes at 0-5 m and 5-10 m, the total dry weight lower than culms stage classes at 10-15 m. The different sizes of culms DBH will influence the rate of total weight of bamboo culms.

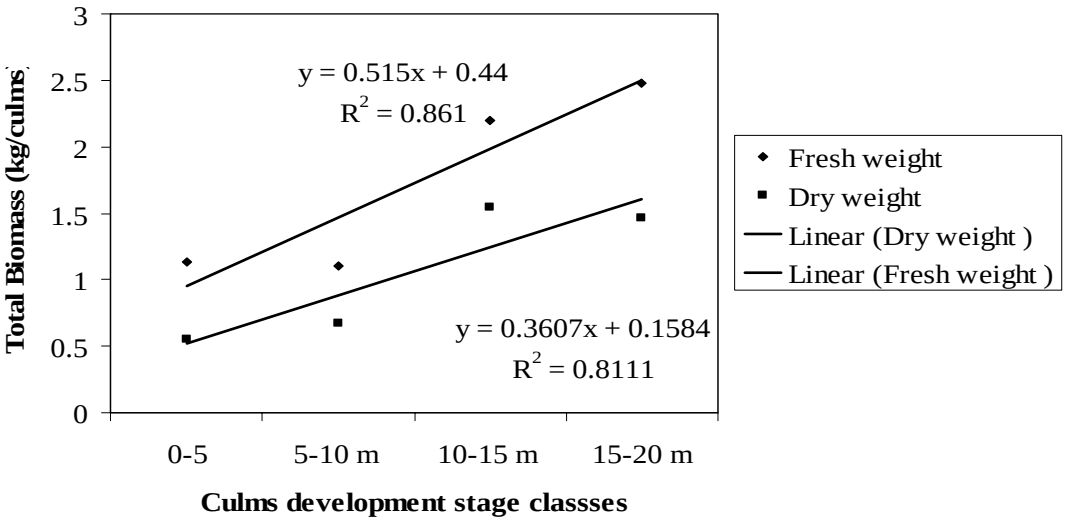

Figure 35 The regression relationship between culms development stage classes and total biomass in fresh and dry weight of *D. asper*

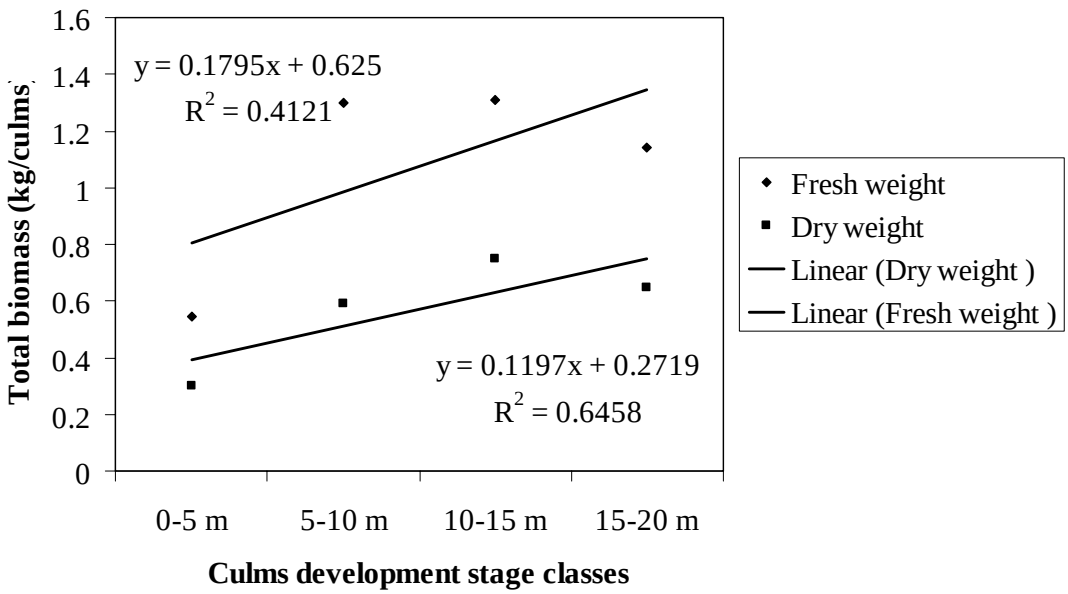

Figure 36 The regression relationship between culms development stage classes and total biomass in fresh and dry weight of *B. bambos*

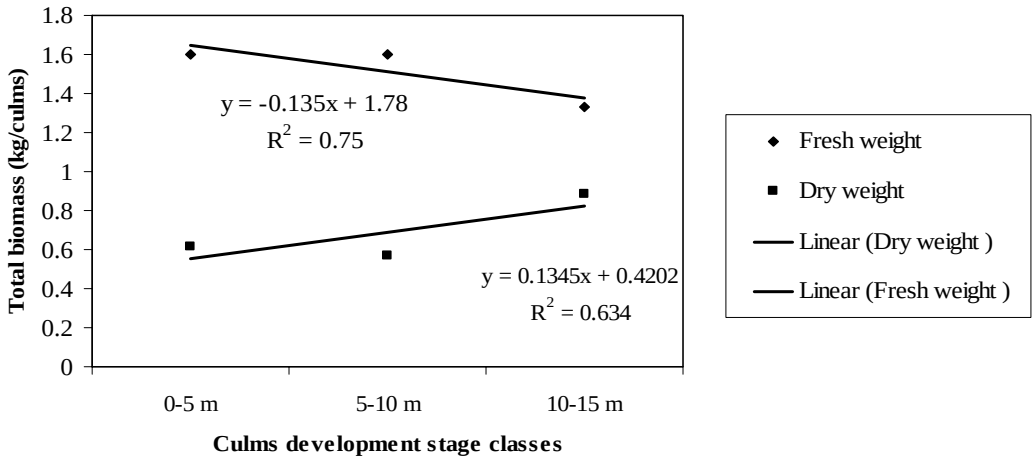

Figure 37 The regression relationship between culms development stage classes and total biomass in fresh and dry weight of *M. humilis*

Table 47 Fresh and dry weight of *Dendrocalamus asper* with different culms development stages classes

Sp. no.	Bamboo culms development stage classes	Fresh weight (kg)								Dry weight (kg)			
		Culms		Branches		Leaves		Total		C	B	L	Total
		S (kg)	Total (kg)	S (kg)	Total (kg)	S (kg)	Total (kg)	S (kg)	Total (kg)				
1.	0-5 m	0.130	2.650	0.200	2.210	0.200	1.000	0.530	5.860	0.090	0.110	0.085	0.286
2.	0-5 m	0.200	2.160	0.200	0.700	0.200	0.800	0.600	3.660	0.074	0.101	0.096	0.270
3.	5-10 m	0.200	3.500	0.200	2.730	0.200	1.000	0.600	7.230	0.123	0.129	0.117	0.370
4.	5-10 m	0.100	2.100	0.200	1.800	0.200	0.940	0.500	4.840	0.080	0.109	0.114	0.304
5.	10-15 m	0.400	11.500	0.200	3.660	0.200	0.580	0.800	15.740	0.235	0.123	0.098	0.463
6.	10-15 m	1.400	42.220	0.200	13.380	0.200	5.600	1.800	61.200	0.960	0.118	0.098	1.176
7.	15-20 m	1.080	33.020	0.200	12.020	0.200	5.180	1.480	50.220	0.611	0.115	0.111	0.837
8.	15-20 m	0.600	14.760	0.200	8.600	0.200	3.000	1.080	26.360	0.412	0.131	0.089	0.632

Note: C = Culms, B = Branches, L = Leaves, S = Sample

Table 48 Total above-ground biomass (kg/culms) for *Dendrocalamus asper*

Sp. no.	Bamboo culms development stage classes	Fresh weight (kg)			Dry weight (kg)			Biomass (kg/culms)			Total above-ground biomass (kg)
		C	B	L	C	B	L	C	B	L	
1.	0-5 m	0.130	0.200	0.200	0.090	0.110	0.085	1.839	1.000	0.427	3.484
2.	0-5 m	0.200	0.200	0.200	0.074	0.101	0.096	0.794	0.353	0.384	1.531
3.	5-10 m	0.200	0.200	0.200	0.123	0.129	0.117	2.160	1.763	0.587	4.509
4.	5-10 m	0.100	0.200	0.200	0.080	0.110	0.114	1.683	0.987	0.536	3.206
5.	10-15 m	0.400	0.200	0.200	0.235	0.130	0.098	67.519	2.375	0.284	67.52
6.	10-15 m	1.400	0.200	0.200	0.960	0.118	0.098	28.964	7.868	2.795	39.627
7.	15-20 m	1.080	0.200	0.200	0.611	0.115	0.112	18.686	6.925	2.869	28.480
8.	15-20 m	0.600	0.200	0.200	0.412	0.131	0.089	10.125	5.674	1.339	17.139

Note : C = Culms, B = Branches, L = Leaves

Table 49 Fresh and dry weight of each bamboo components of *Bambusa bambos*

Sp. no.	Bamboo culms development stage classes	Fresh weight (kg)								Dry weight (kg)			
		Culms		Branches		Leaves		Total		C	B	L	Total
		S (kg)	Total (kg)	S (kg)	Total (kg)	S (kg)	Total (kg)	S (kg)	Total (kg)				
1.	0-5 m	0.050	3.250	0.100	0.100	0.110	0.110	0.450	4.360	0.028	0.066	0.061	0.154
2.	0-5 m	0.050	0.750	0.125	0.125	0.110	0.110	0.450	0.990	0.034	0.054	0.058	0.145
3.	5-10 m	0.300	6.420	0.200	6.820	0.200	1.000	0.700	14.240	0.149	0.098	0.078	0.324
4.	5-10 m	0.200	5.300	0.200	1.100	0.200	1.410	0.600	7.810	0.105	0.092	0.071	0.267
5.	10-15 m	0.200	8.010	0.200	0.280	0.200	0.260	0.600	8.550	0.124	0.105	0.099	0.329
6.	10-15 m	0.310	11.160	0.200	1.250	0.200	1.050	0.710	13.460	0.159	0.117	0.142	0.418
7.	15-20 m	0.240	9.080	0.200	1.130	0.200	0.600	0.640	10.810	0.149	0.115	0.117	0.381
8.	15-20 m	0.100	4.700	0.200	0.600	0.200	0.500	0.500	5.800	0.063	0.103	0.099	0.265

Note : C = Culms, B = Branches, L = Leaves, S = Sample

Table 50 Total above-ground biomass (kg/culm) for *Bambusa bambos*

Sp. no.	Bamboo culms development stage classes	Fresh weight (kg)			Dry weight (kg)			Biomass (kg/culm)			Total above-ground biomass (kg)
		C	B	L	C	B	L	C	B	L	
1.	0-5 m	0.050	0.100	0.110	0.028	0.066	0.061	1.801	0.066	0.061	1.927
2.	0-5 m	0.050	0.125	0.110	0.037	0.054	0.058	0.504	0.054	0.058	0.615
3.	5-10 m	0.300	0.200	0.200	0.149	0.098	0.078	3.182	3.328	0.390	6.900
4.	5-10 m	0.200	0.200	0.200	0.105	0.092	0.071	2.777	0.506	0.499	3.782
5.	10-15 m	0.200	0.200	0.200	0.124	0.105	0.099	4.974	0.147	0.129	5.250
6.	10-15 m	0.310	0.200	0.200	0.159	0.117	0.142	5.724	0.733	0.746	7.203
7.	15-20 m	0.240	0.200	0.200	0.149	0.115	0.117	5.652	0.650	0.350	6.653
8.	15-20 m	0.100	0.200	0.200	0.063	0.103	0.100	2.975	0.308	0.249	3.531

Note : C = Culms, B = Branches, L = Leaves

Table 51 Fresh and dry weight of each bamboo components of *Melocanna humilis*

Sp. no.	Bamboo culms development stage classes	Fresh weight (kg)								Dry weight (kg)			
		Culms		Branches		Leaves		Total		C	B	L	Total
		S (kg)	Total (kg)	S (kg)	Total (kg)	S (kg)	Total (kg)	S (kg)	Total (kg)				
1.	0-5 m	0.400	1.500	0.200	0.630	0.200	1.100	0.800	3.230	0.057	0.147	0.112	0.315
2.	0-5 m	0.400	1.600	0.200	0.320	0.200	0.450	0.800	2.370	0.062	0.123	0.112	0.298
3.	5-10 m	0.300	1.240	0.200	0.340	0.200	0.710	0.700	2.290	0.049	0.118	0.111	0.279
4.	5-10 m	0.500	2.030	0.200	0.800	0.200	0.830	0.900	3.660	0.067	0.118	0.108	0.293
5.	10-15 m	0.220	1.800	0.200	1.100	0.200	0.920	0.620	2.240	0.163	0.137	0.118	0.417
6.	10-15 m	0.310	1.070	0.200	1.400	0.200	1.210	0.710	13.680	0.206	0.142	0.118	0.466

Note : C = Culms, B = Branches, L = Leaves, S = Sample

Table 52 Total above-ground biomass (kg/culm) for *Melocanna humilis*

Sp. no.	Bamboo culms development stage classes	Fresh weight (kg)			Dry weight (kg)			Biomass (kg/culm)			Total above-ground biomass (kg)
		C	B	L	C	B	L	C	B	L	
1.	0-5 m	0.400	0.200	0.200	0.057	0.147	0.112	0.218	0.462	0.618	1.292
2.	0-5 m	0.400	0.200	0.200	0.063	0.123	0.112	0.252	0.197	0.253	0.701
3.	5-10 m	0.300	0.200	0.200	0.049	0.119	0.112	0.201	0.202	0.396	0.799
4.	5-10 m	0.500	0.200	0.200	0.067	0.118	0.108	0.271	0.471	0.448	1.190
5.	10-15 m	0.220	0.200	0.200	0.163	0.137	0.118	1.332	0.751	0.541	2.624
6.	10-15 m	0.310	0.200	0.200	0.206	0.142	0.118	0.710	0.993	0.715	2.417

Note : C = Culms, B = Branches, L = Leaves

Table 53 Production of biomass of *D. asper*, *B. bambos* and *M. humilis* on unit per culms per clumps (tons/culms)

Bamboo species	Bamboo culms development stage classes	Average culms diameter (cm)	Average height (m)	Average basal area (cm)	Average number of culms per clumps	Biomass (kg/culm)			Total above-ground biomass (kg/culms)	Grand total above-ground biomass (tons/culm)
						Culms	Branches	Leaves		
D. asper	0-5 m	2.45	5.00	4.83	29	1.32	0.68	0.41	2.51	2.40
	5-10 m	2.85	6.75	6.43		1.92	1.37	0.56	3.86	
	10-15 m	6.60	14.50	35.00		48.24	5.12	1.54	53.57	
	15-20 m	5.80	17.50	27.38		14.41	6.30	2.10	22.81	
B. bambos	0-5 m	1.25	4.50	1.23	125	1.15	0.06	0.06	1.27	2.24
	5-10 m	4.60	9.50	16.80		2.98	1.92	0.44	5.34	
	10-15 m	5.40	12.30	23.29		5.35	0.44	0.44	6.23	
	15-20 m	4.40	15.00	15.60		4.31	0.48	0.30	5.09	
M. humilis	0-5 m	3.20	5.00	8.05	34	0.23	0.33	0.44	0.99	1.53
	5-10 m	2.85	6.00	6.40		0.24	0.34	0.42	0.99	
	10-15 m	6.40	11.00	32.20		1.02	0.87	0.63	2.52	

The grand total biomass values of the bamboo species were multiplied with the average number of culms per clumps, to calculate the production of biomass (tons/culms).