Biomass estimation of *Bambusa nutans* subspecies *cupulata* grown at Eastern Terai, Nepal

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With a view to prepare biomass table of *Bambusa nutans* subspecies *cupulata* grown at Belbari, Morang district of Eastern Terai, a total of 150 culms were selected from ninty-eight clumps. Measurements of Diameter at 15 cm of the base (D_{15}), vertical height of the culm and green weight of the culm, branches and foliage were taken in the field. The sampled green weight was oven dried in Kathmandu. To estimate the biomass, regression model was developed on the basis of oven dry and green weight. The model used was $W = a + b * (D^2L)$. Based on the oven dry weight, the R^2 values obtained for culm, branch and foliage components were 90, 82 and 73 per cent respectively. Similarly, R^2 values for culm and foliage components on the basis of green weight were 90 and 73 per cent respectively. The R^2 values obtained for branch and foliage components were slightly lower as compared to the culm. The validity is to be done before applying this equation to different site conditions.

Key words: Biomass, bamboo, *Bambusa nutans* subspecies *cupulata*, Nepal

Bamboos are one of the most widely used products. It's products are already in everyday use by about 2.5 billion people in the world (Scurlock *et al.*, 2000). It has over 1500 uses and has tremendous versatility (Rai and Chauhan, 1998). In Nepal, they are one of the most common plant species grown on farmland. People perceive this species as an alternate to tree for fulfilling their demand of forest products (Das and Oli, 2001). With its varied uses such as construction materials, woven products, agricultural implements, fodder, vegetables and scaffolding and in stabilizing slip-prone slopes, bamboos are in great demand by the rural households in Nepal.

Occurrence of bamboo is more common in the eastern half of the country from Dhaulagiri to Sikkim Boarder, as high as 4000 m (Stapleton, 1994). There are over 75 genera and 1250 species of the bamboos in the world (FAO, 1978) and 80% of this resource is found in South and South East Asia and China (Sharma, 1988). In Nepal, 12 genera and more than 50 species of bamboo have been recorded so far (TIS, 2004). Out of the 75 districts of Nepal, 73 are known to have one or more species of bamboo. It has been estimated that the total growing stock of bamboo in Nepal is around 15 million cubic metres with an approximate biomass value of 1060 million tons (Karki and Karki, 1995).

Bambusa nutans subspecies *cupulata* is one of the most commonly cultivated bamboos on the farmlands from the Terai up to 1500 masl. It prefers well-drained moist site with moderate shade (TIS, 2004, Stapleton, 1994). It has strong culms, which are largely used for construction and scaffolding purposes. The culms are well apart and can reach a maximum diametre of 10 cm and a length of 23 m in good site conditions. Culms are very straight with internode length of 38-45 cm. Leaves are linear lanceolate, 15-30 cm long and 2.5-4.0 cm broad with green colour. The leaves of this species are considered one of the best fodders for livestock both in the Terai and Midhills (TIS, 2004).

Despite the multiple benefits obtained from bamboos, limited information has so far been published on its potential of biomass production. On the basis of oven dry and green weight, biomass table of *Bambusa nutans* subspecies *nutans* and *Bambusa tulda* has been prepared (Oli, 2003; Oli, 2005) earlier. However, previous studies have focused on distribution, growth performance and culm production aspects. It has been reported that survival, average height, average diameter and culms production of this species was found higher than other four bamboo species. (Thapa *et al.,* 1998). As there is a growing demand of bamboo products in the country, the information on estimation of biomass could be beneficial for managing the

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bamboo resources in a more practical way. This study, therefore, aims at providing information on biomass of *Bambusa nutans* subspecies *cupulata*, which is of use to forestry professionals, private growers, local forest user groups and other interested individuals.

Materials and methods

A trial on establishment and management of bamboo was established by the Department of Forest Research and Survey at Belbari, Morang district of eastern region in 1991. *Bambusa nutans* subspecies *nutans* (Taru Bans), *Bambusa nutans* subspecies *cupulata* (Mal Bans), *Bambusa tulda* (Japhta Bans), *Bambusa balcooa* (Dhanu Bans) and *Dendrocalamus giganteus* (Rakshasi Bans) were planted at Belbari (Thapa *et al*., 1998). Of the five bamboo species planted, *Bambusa nutans* subspecies *cupulata* was selected for the study purposes. The reason for selecting bamboo species for biomass estimation is due to its varied uses and wide occurrence in Nepal and lack of comprehensive documentation on biomass estimation of this species.

The site is located at an altitude of 155 masl, soil is loam to silt loam. There was Sal (*Shorea robusta)* forest 3 to 4 years before the establishment of the trial. The average annual rainfall is 1737 mm and average maximum and minimum temperature are 30^0 C and 18.2^0 C respectively (HMG/N, 1997). The plants produced from single node culm cuttings taken from Belbari, Morang was the source of parent materials of this species. These cuttings were propagated in the Hetauda nursery, before being taken to planting site at Belbari. Soil heaping was carried out in each clump in 1993 and the oldest culms were cut and removed in the winter of 1996 (Thapa *et al*., 1998).

Ninty-eight clumps representing varying age and diametre classes were chosen. The total number of culms from each clump was counted. From each clump, at least 1 culms totaling 150 were taken for the study. Measurements of Diameter at 15 cm of the base (D_{15}), vertical length of the culm and green weight of the culm, branches and foliage were taken in the field. Representative eighteen culms were selected for sub-samples of culm, branch and foliage. These sub-samples were brought into the laboratory in Kathmandu and oven-dried at 105^O C until a constant weight was attained.

To convert the fresh weight of culm, branch and foliage components into oven dry weight, sub-sample's percentage dry matter values were used.

Dry matter values = [(Oven dry weight/Fresh weight) x 100]

With the use of above formula, a conversion factor of 0.44, 0.48 and 0.37 was used for converting fresh weight to oven dry weight of culm, branch, and foliage respectively. To estimate the biomass, regression model was developed on the basis of oven dry weight. Biomass table for culm and foliage was also prepared on the basis of green weight. The model used was $(W) = a + b * (D^2L)$, where 'W' is the weight, 'D' is the diametre at 15 cm, 'L' is the vertical length of the culm, and 'a' and 'b' are the constants.

Results and discussion

A total of 48 per cent dry matter content was found in the branch of *Bambusa nutans* subspecies *cupulata.* The culm and foliage has 44 and 37 per cent of dry matter content values respectively. The dry matter content of culm, branch and foliage components of *Bambusa nutans* subspecies *nutans* grown at the same site were found to be 47.3, 41.1 and 38.2 per cent respectively (Oli, 2003). Similarly, the dry matter content of culm, branch and foliage components of *Bambusa tulda* grown at the same site were found to be 48, 53 and 36 per cent respectively (Oli, 2005).

Using the regression model of $(W) = a + b * (D^2L)$, biomass of all the components (culm, branch and foliage) were calculated. Based on the oven-dried weight, the R^2 values obtained for culm, branch and

Table 1: Biomass table for culm on the basis of oven dry weight (in kg)

D_{15} (cm)	Height (m)													
	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	2.15	2.30	2.44	-	-	-	-	-	-	-	-	-	-	-
5	2.56	2.79	3.02	3.25	3.47	3.70	3.93	4.16	4.38	4.61	-	-	-	-
6	-	3.39	3.72	4.05	4.37	4.70	5.03	5.36	5.68	6.01	6.34	-	-	-
7	-	-	4.55	4.99	5.44	5.88	6.33	6.78	7.22	7.67	8.11	8.56	-	-
8	-	-	-	6.08	6.67	7.25	7.83	8.41	8.99	9.58	10.16	10.74	11.33	-
9	-	-	-	-	8.06	8.79	9.53	10.27	11.01	11.74	12.48	13.22	13.96	14.69

a= 1.426 b= 0.0091 SE= 0.919 R^2= 90%

foliage components were 90, 82 and 73 per cent respectively. The R^2 values for branch and foliage were slightly lower as compared to the culm. It is argued that the prediction of leaf yield from biomass equations is less accurate and more site specific than for the components of stem, branch and total tree weight (Satoo and Madgwick, 1982). Biomass tables for culm, branch and foliage components based on oven dried weight are presented in Table 1, 2 and 3 respectively.

Biomass equations are normally prepared on an oven dry weight basis to facilitate comparison with other sites, species and seasons (Hawkins, 1987). However, bamboo culms are sold on a fresh weight basis in both the rural and urban areas of Nepal. So, biomass table for culm based on green weight was also prepared. Bamboo leaves are used as fodder in some areas where there is fodder deficit. Hence, biomass table for foliage was prepared on the basis of green weight. Based on the green weight, the R^2 values obtained for culm and foliage components were 90 and 73 per cent respectively. Biomass tables based on green weight for culm and foliage are given in Table 4 and 5 respectively. Rao and Nagarajaih (1991) reported from India that total biomass of planted *Bambusa arundinacea* (retz.) wild of 3 years age was 8528 Kg per ha. The total above ground biomass of *Dendrocalamus strictus* in India was 4-22 tons/ha (Tripathi and Singh, 1994). On the other hand the figure ranges from 122-287 tons/ha for *Bambusa bambos* in India (Shanmughavel and Francis, 1996).

Applicability of the table

Considering the wide use of bamboos these days, these biomass tables may help provide useful information on above ground biomass to forestry professional, bamboo growers, forest user groups and other interested individuals. The biomass estimation

Table 2: Biomass table for branch on the basis of oven dry weight (in kg)

D_{15} (cm)	Height (m)													
	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	0.17	0.19	0.21	-	-	-	-	-	-	-	-	-	-	-
5	0.22	0.25	0.28	0.30	0.33	0.36	0.39	0.41	0.44	0.47	-	-	-	-
6	-	0.32	0.36	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	-	-	-
7	-	-	0.46	0.51	0.57	0.63	0.68	0.73	0.78	0.84	0.89	0.95	-	-
8	-	-	-	0.65	0.72	0.79	0.86	0.93	1.00	1.07	1.14	1.21	1.28	-
9	-	-	-	-	0.88	0.97	1.06	1.15	1.24	1.33	1.42	1.51	1.60	1.69

a= 0.0839 b=0.0011 SE= 0.143 R^2= 82%

Table 3: Biomass table for foliage on the basis of oven dry weight (in kg)

D_{15} (cm)	Height (m)													
	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	0.039	0.045	0.051	-	-	-	-	-	-	-	-	-	-	-
5	0.057	0.067	0.077	0.087	0.097	0.106	0.116	0.127	0.137	0.147	-	-	-	-
6	-	0.093	0.107	0.122	0.136	0.151	0.165	0.179	0.194	0.208	0.222	-	-	-
7	-	-	0.144	0.163	0.183	0.203	0.222	0.242	0.261	0.281	0.301	0.320	-	-
8	-	-	-	0.211	0.237	0.263	0.288	0.314	0.339	0.365	0.391	0.416	0.442	-
9	-	-	-	-	0.298	0.331	0.363	0.395	0.428	0.460	0.493	0.525	0.557	0.590

a= 0.0067 b=0.0004 SE= 0.061 R^2= 73%

Table 4: Biomass table for culm on the basis of green weight (in kg)

D_{15} (cm)	Height (m)													
	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	4.90	5.23	5.56	-	-	-	-	-	-	-	-	-	-	-
5	5.83	6.35	6.86	7.38	7.90	8.42	8.93	9.45	9.97	10.49	-	-	-	-
6	-	7.71	8.46	9.20	9.95	10.69	11.44	12.18	12.93	13.67	14.42	-	-	-
7	-	-	10.34	11.36	12.37	13.38	14.40	15.41	16.43	17.44	18.46	19.47	-	-
8	-	-	-	13.84	15.16	16.49	17.81	19.14	20.46	21.79	23.11	24.44	25.76	-
9	-	-	-	-	18.33	20.01	21.68	23.36	25.04	26.72	28.39	30.07	31.75	33.42

a= 3.242 b= 0.021 SE= 2.090 R^2= 90%

Table 5: Biomass table for foliage on the basis of green weight (in kg)

D_{15} (cm)	Height (m)													
	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	0.098	0.114	0.130	-	-	-	-	-	-	-	-	-	-	-
5	0.143	0.168	0.193	0.218	0.243	0.268	0.293	0.318	0.343	0.368	-	-	-	-
6	-	0.234	0.270	0.306	0.342	0.378	0.414	0.450	0.486	0.522	0.558	-	-	-
7	-	-	0.361	0.410	0.459	0.508	0.557	0.606	0.655	0.704	0.753	0.802	-	-
8	-	-	-	0.530	0.594	0.658	0.722	0.786	0.850	0.914	0.978	1.042	1.106	-
9	-	-	-	-	0.747	0.828	0.909	0.990	1.071	1.152	1.233	1.314	1.395	1.476

a= 0.018 b= 0.001 SE= 0.165 R^2= 73%

is confined to the site condition of Belbari of Morang district. Moreover, some management practices such as soil heaping and removal of the oldest culms were carried out in the past. Hence, the above tables may not necessarily represent the *Bambusa nutans* subspecies *cupulata* grown at other site conditions and management prescriptions. It is, therefore, recommended to pre-test the table before applying to other site conditions.

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