Biomass estimation of some fast growing trees in the eastern Terai, Nepal

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With an aim to select trees, which yield higher biomass *Acacia auriculiformis*, *Acacia catechu*, *Dalbergia sissoo*, *Eucalyptus camaldulensis*, *Eucalyptus tereticornis*, and *Leucaena leucocephala* were planted in 1985 at Tarahara of Sunsari District. Destructive sampling carried out in January 1991 showed that the green above-ground wood varied from 19.5 tonnes/ha in *E. tereticornis* to 108.4 tonnes/ha in *E. camaldulensis*. Productivity of oven dry above-ground wood ranged from 1.1 tonnes/ha/year in *E. tereticornis* to 7.6 tonnes/ha/year in *E. camaldulensis*. Stocking was the highest (1776 stems per ha) in *A. auriculiformis*, and the lowest (528 stems per ha) in *E. tereticornis*. Percentage contribution of stemwood to total above-ground wood was the highest (91.6%) in *E. camaldulensis* and the lowest (72.7%) in *A. catechu*. The accumulation of branchwood was higher (27.3%) for *A. catechu* followed by *A. auriculiformis* (25.7%). Due to variation in moisture content of tree species, the trend was not found similar in oven-dried biomass production particularly for stemwood of *A. auriculiformis* and *E. tereticornis*, branch wood of *A. auriculiformis* and *D. sissoo*, however, the rank of five species in green above-ground wood production was the same in oven dried above-ground wood production. Precision percent was found satisfactory in most cases (15.7 to 19.8 %) for dry above-ground wood, except *E. tereticornis*) whereas it was too high for tree components and above-ground wood of *E. tereticornis* (48.8 to 54.4 %).

Keywords : Biomass, fast growing trees, productivity, *Acacia auriculiformis*, *Acacia catechu*, *Dalbergia sissoo*, *Eucalyptus camaldulensis*, *Eucalyptus tereticornis*, Nepal

Fuelwood is the main source of cooking and heating in rural areas of Nepal. The use of fuelwood by rural people is about 70% whereas it is only 31% in urban areas (Adhikari 1999). The ever increasing population in the Terai demands a huge amount of firewood for cooking and heating purposes. On the other hand forest areas are decreasing annually. Establishment of fast growing tree plantations is one way to supply fuelwood for households, brick factories and tobacco barn houses in the Terai as the hydropower, biogas, LPG (cooking gases), fuel and solar energy are beyond the reach of the poor people.

In view of the scenerio the present paper aims to select trees with higher wood biomass production under short rotation.

Methods

The trial was set up in July 1985 in 0.735 ha at a spacing of 2.5 m x 2.5 m (For description of study site see Thapa, 1998). Six species namely, *Acacia auriculiformis*, *Acacia catechu*, *Eucalyptus camaldulensis*, *Eucalyptus tereticornis*, and *Leucaena leucocephala* were raised from seed in Hetauda Research Nursery. Stumps (root and shoot cuttings) of *Dalbergia sissoo* were raised in local Range Office Nursery at Tarahara. Stumps of about fifteen months old and polypot seedlings of three to four months were planted. However, some of these species e. g. *A. auriculiformis*, *E. camaldulensis*, and *E. tereticornis* have already performed well on growth and yield in the central Terai / bhabar region of Nepal, although they have not been tested in the Eastern region.

Randomised complete block design with four replications and six treatments was chosen. Each plot comprised of 49 plants (7x7 plants) of each species. Only the inner 5x5 trees were used for assessment leaving one outer line as buffer. Replacement was carried out only once within one month of the trial plot set-up. No irrigation or fertilizer were applied. Spot cultivation was done at 0.5 m radius around each plant twice a year for the first three years. *Eupatorium* spp. (banmara) were cut at the ground level in the winters of 1989 and 1990, and burned down. A fireline of about four metres was maintained every year along the fencing.

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Four to seven trees of each species in each plot of each block were selected with dbh range from lowest to the highest to cover the entire range in the population for destructive sampling which was carried out in January 1991. For each species, healthy and healthy 17 to 22 sample trees were selected and marked from the inner core of 5x5 trees only. Diameters at breast height (over bark) were recorded for marked trees before felling. 20 to 25 percent of the trees of each species in each plot were cut down with a bow saw at about 10 cm above ground. After felling, the total length of the tree was measured. Leaves were separated from branches and the stem was cut into 1.5 to 2.0 m. Stem sections and branches were weighed separately and recorded. Representative sub-samples of each component (stem and branch) were collected for the determination of moisture content and dry matter percent. Discs of about 5 to 10 cm width from lower, middle and upper portions of the stem section (3 to 4 sub-sample pieces) of various sized trees (small, medium and large trees) of each species were weighed separately and fresh weights recorded. A similar method was applied for branch sub-samples of the species. These sub-samples were brought to the laboratory in Kathmandu and oven dried at 105^0 C for 48 hours until a constant weight was attained. Due to the difficulty in taking sub-samples of every tree sampled, branch and bole sub-samples of five to six sampled trees were used to find out the mean dry matter percent which was used to determine the oven dry weight of bole and branches of each species. Sample's percentage dry matter values {(Oven-dry weight/fresh weight) x 100} were used to convert fresh to dry weights for the general data.

Table 1: Green weights (kg per tree), standard errors, and confidence intervals of tree components and above-ground wood

	Stemwood			Branchwood			Above-ground wood		
Species	Mean (kg /tree)	SE(kg)	CI at 95%	Mean (kg /tree)	SE(kg)	CI at 95%	Mean (kg /tree)	SE (kg)	CI at 95%
Acacia auriculiformis	30.01 (74.3)	2.38	4.66	10.37 (25.7)	1.04	2.04	40.38 (100)	3.41	6.69
Acacia catechu	54.93 (72.7)	3.73	7.32	20.6 (27.3)	2.41	4.71	75.53 (100)	·6.1	11.96
Dalbergia sissoo	32.35 (75.5)	3.11	6.09	10.49 (24.5)	1.22	2.4	42.84 (100)	4.33	8.5
Eucalyptus camaldulensis	76.73 (91.6)	7.42	14.55	6.95 (8.4)	0.6	1.18	83.68 (100)	8.02	15.73
Eucalyptus tereticornis	30.77 (83.3)	7.65	48.7	6.17 (16.7)	1.71	54.3	36.94 (100)	9.36	18.34

CI- for confidence interval. Figures in parenthesis indicate the percent of stem and branchwood to above-ground wood.

With the use of sampled data, various models as given by Thapa (1999) were tested and the model, Ln W= a+b Ln DBH where W stands for weight of tree components and above-ground wood (agw), DBH for diameter at breast height over bark; a and b regression constants, was selected to calculate estimate tree components (stem and branchwood), and above-ground wood of five species. Conversion factors from green to oven dry were used to find out the oven dry weights of tree components and above-ground wood. Due to mistake in the values of slope and intercept of green stemwood of *A. catechu* (Thapa 1999), the values (slope= -1.376, intercept= 2.17 and correction factor= 0.0406) was used.

The mean annual production (tonnes/ha/year) and the rate of accumulation of dry matter (kg/tree/year) of the five species was obtained by dividing the total wood biomass of each component and means of non-photosynthetic components by at 5.5 years.

Twenty trees of each *Acacia auriculiformis*, and *Dalbergia sissoo*, 22 trees of *Acacia catechu*, 21 trees of *Eucalyptus camaldulensis*, and 17 trees of *Eucalyptus tereticornis* were cut down for the estimation of wood biomass.

Results

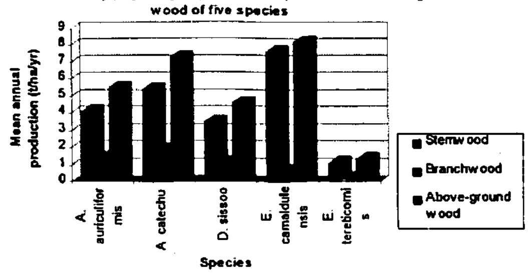
Mean weights of green tree component and above-ground wood (stem+branch) of standing trees are given in Table 1.

Production of green stemwood was highest (76.73 kg/tree) in *E. camaldulensis*, and lowest (30.01

kg/tree) in *A. auriculiformis*. In branchwood production, it ranged from 6.17 kg/tree in *E. tereticornis* to 20.6 kg/tree in *A. catechu*. Production of agw was highest (stem plus branchwood) for *E. camaldulensis* followed by *A. catechu* and lowest in *E. tereticornis* (Table 1).

With regard to the percentage of tree components to above-ground wood biomass, the stem contributed more than 91%, the highest in *E. camaldulensis*, the least contribution of stemwood was recorded in *A. catechu* (72.7%), however, there was less variation in the stemwood (74.3, 72.7, and 75.5 %) of *A. auriculiformis*, *A. catechu*, and *D. sissoo* respectively. As expected branchwood only contributed 8.41% to agw in *E. camaldulensis* (Table 1 and Chart 1).

Chart 3: Productivity (dry t/ha/year) of tree components and above-ground wood of five species



Eucalyptus camaldulensis produced the maximum mean dry stemwood biomass (32.07 kg/tree), followed by *A. catechu* (25.07 kg/tree) and the lowest stemwood biomass was produced by *E. tereticornis*. Out of five species, *A. auriculiformis* had the lowest above-ground wood (12.73 kg/tree)

Table 2: Oven dry weights (kg per tree), standard errors, confidence intervals, and precision percentages of tree components and above-ground wood

Species	Stemwood				Branchwood				Above-ground wood			
	Mean (kg /tree)	SE (kg)	CI at 95%	P (%)	Mean (kg /tree)	SE (kg)	CI at 95%	P (%)	Mean (kg /tree)	SE (kg)	CI at 95%	P (%)
Acacia auriculiformis	12.78	1.01	1.98	15.5	4.45	0.45	0.88	19.8	17.23	1.46	2.86	16.5
Acacia catechu	25.27	1.70	3.37	13.3	9.01	1.05	2.06	22.9	34.28	2.75	5.39	15.7
Dalbergia sissoo	14.17	1.36	2.67	18.8	4.59	0.54	1.05	22.9	18.76	1.89	3.71	19.8
Eucalyptus camaldulensis	32.07	3.10	6.08	18.9	2.69	0.23	0.46	17.1	34.76	3.34	6.54	18.8
Eucalyptus tereticornis	11.38	2.83	5.55	48.8	2.28	0.63	1.24	54.4	13.66	3.46	6.79	49.7

CI = confidence interval, and P for precision

Chart 1: Percentage of dry stem and branch wood to above-ground wood of five species

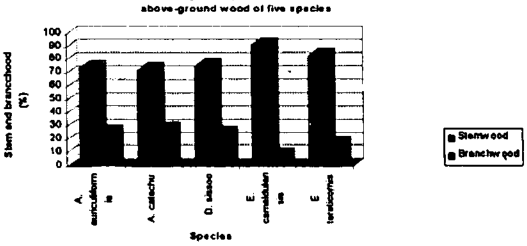
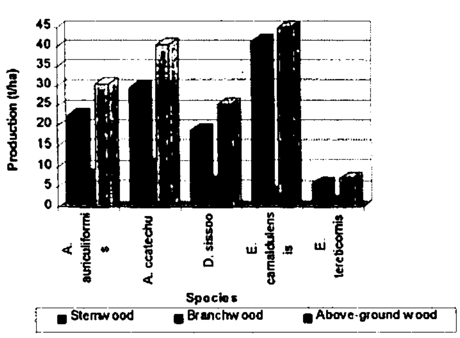


Chart 2: Production of oven dry wood biomass (t/ha) of stem, branch, and above-ground wood of five species



followed by *E. tereticornis* (12.67 kg/tree). The mean dry branch wood production was the highest (9.01 kg/tree) in *A. catechu* which was about four times higher than the branchwood biomass of *E. camaldulensis*. *A. auriculiformis* and *D. sissoo* attained more or less similar bramchwood biomass. *E. camaldulensis* produced the highest dry agw biomass (34.76 kg/tree) followed by *A. catechu* (34.27 kg/tree) (Table 2).

With the exclusion of *E. tereticornis*, precision percent varied from 13.3 for dry stemwood of *A. catechu* to 22.9% for dry branchwood of *A. catechu* and *D. sissoo*. Green agw biomass production varied from 19.5 t/ha in *E. tereticornis* to 108.4 t/ha in *E. camaldulensis* followed by *A. catechu* (89.4 t/ha) and the similar trend was found for dry agw biomass production (Table 3 and Chart 2). Mean annual production of dry agw was the highest 8.2 tonnes/ha/year in *E. camaldulensis* followed by *A. catechu* (7.3 tonnes/ha/year) and the lowest in *E. tereticornis* (1.3 tonnes/ha/year) (Table 5 and Chart 3). *E. camaldulensis* had the highest rate of accumulation of green matter (13.95 kg/tree/year) and oven dry (5.83 kg/tree/year) stemwood biomass followed by *A. catechu* (green 9.99 and oven dry 4.59 kg/tree/year) and the similar trend remained for green and oven dry agw and the lowest green and oven dry agw was in *E. tereticornis* (Table 5).

Discussions and conclusion

It is interesting to note that the stocking was found highest (1776 stems) in *A. auriculiformis*, even though survival was the second lowest (69%). The highest stocking is due to the presence of a number of forked trees (672 trees) below 1.3 m height which were recorded as the separate ones. Such forking habit of this species is particularly valuable for firewood production. Mean green agw of *A. auriculiformis* was lower than *E. tereticornis* but stocking was higher which have increased wood production per unit area. Both average figures and stocking of *E. tereticornis* were lower resulting in less wood biomass production per unit area.

Surprisingly, the survival and growth of *E. tereticornis* was found too low as compared with the growth and production of this species at other sites of Nepal. Hence, it could not be ascertained that *E. tereticornis* is the poorer species for growth and wood biomass production in the eastern Terai. It needs further confirmation.

E. camaldulensis (Petford provenance) was found to be the most productive species in Sagarnath, Nepal. Dry stem and branchwood production of this species (in Sagarnath Block 5A) was 63.4 t/ha at the age of 4 years (mean annual production 15.9 t/ha/year) whereas dry agw was only 45.0 t/ha at the age of 5.5 years (MAP 8.2 t/ha/year) (Table 3 and 4) at Tarahara. The yield (dry stem and branch) of *D. sissoo* on a good site was 36.6 tonnes/ha at Sagarnath at 5 years (Hawkins 1987) which was grown at a spacing of 2.5 x 2.5 m. The agw at Sagarnath was recorded 44.7 % more than that of the agw at Tarahara. All the plants were planted into disced soil and maintained in weed free conditions for 18 months followed by intercropping. The lower yield of these two species, *E. camaldulensis* and *D. sissoo* at Tarahara may be due to insufficient weeding and competition in moisture availability with the weeds *Eupatorium* spp. For instance, *D. sissoo* produced only 24.4 t/ha at 9.5 years in Sagarnath Laximinia site, a dry site, in Nepal at a spacing of 2x2 m where planting was done by then Forest Survey and Research Office. Pit weeding was carried out for the first four years (Hawkins, 1987). Under full cultivation for the first 2.5 years more the five *Eucalyptus* species, dry stem plus branch wood biomass recorded 43.9 t/ha at the age of 3.5 years at a spacing of 2 x 2 m at Adabhar, Nepal (Hawkins 1986). It reveals that pit weeding is not sufficient for the early growth of these species from the experience at Adabhar and Sagarnath in Nepal (Hawkins 1986; White 1986) and the results of Tarahara. Large quantities of *Eupatorium* weeds and *Imperata cylindrica* in the Tarahara plot may have created moisture and nutrient deficiency particularly in the dry season which may have reduced the early growth of these species. Despite pit weeding, full cultivation followed by intercropping is not widely adopted in district and community plantations, however it would obviously seem to increase the yield. It seems essential to maintain weed free conditions for better growth of these species for the first three

Table 3: Survival percent, stocking, green and oven dry weights (kg per tree) of tree components and above-ground wood

Species	S (%)	Stocking	Green standing biomass (tonnes/ha)*			Oven dry standing biomass (tonnes/ha)*		
			Stem	Branch	Stem plus Branch	Stem	Branch	Stem plus Branch
Acacia auriculiformis	69	1776	53.3	18.4	71.7	22.7	7.9	30.6
Acacia catechu	74	1184	65.0	24.4	89.4	29.9	10.7	40.6
Dalbergia sissoo	84	1344	43.5	14.1	57.6	19.1	6.2	25.3
Eucalyptus camaldulensis	81	1296	99.4	9.0	108.4	41.5	3.5	45.0
Eucalyptus tereticornis	33	528	16.2	3.3	19.5	6.0	1.2	7.2

* standing biomass includes sampled trees also. S stands for survival.

Table 4: Productivity (tonnes/ha/year) of tree components and above-ground wood of five species

Species	Green biomass (tonnes/ha/year)			Oven dry biomass (tonnes /ha /year)		
	Stem	Branch	Stem + Branch	Stem	Branch	Stem + Branch
Acacia auriculiformis	9.7	3.3	13.0	4.1	1.4	5.5
Acacia catechu	11.8	4.4	16.2	5.4	1.9	7.3
Dalbergia sissoo	7.9	2.6	10.5	3.5	1.1	4.6
Eucalyptus camaldulensis	18.1	1.6	19.7	7.6	0.6	8.2
Eucalyptus tereticornis	2.9	0.6	3.5	1.1	0.2	1.3

Table 5: Rate of accumulation of green and dry matter of tree components and above-ground wood

Species	Green biomass (kg/tree/yr)			Oven dry biomass (kg/tree/yr)		
	Stem	Branch	Stem + Branch	Stem	Branch	Stem + Branch
Acacia auriculiformis	5.46	1.89	7.35	2.32	0.81	3.13
Acacia catechu	9.99	3.75	13.74	4.59	1.64	5.23
Dalbergia sissoo	5.88	1.91	7.79	2.58	0.83	3.41
Eucalyptus camaldulensis	13.95	1.26	15.21	5.83	0.49	6.32
Eucalyptus tereticornis	5.59	1.12	6.71	2.07	0.41	2.48

years after planting. The weed growth can be controlled as suggested by Hawkins (1986) for the enhancement of production at a low cost by planting agricultural crops.

In Jatilihur, West Java of Indonesia, Wiersum and Ramlan (1982) found the green biomass production of stemwood, branchwood and twigs as 46.2 t/ha and 18.4 t/ha resulting in total above-ground wood 64.6 t/ha at 4 years whereas at Tarahara, *A. auriculiformis* attained a dry stem and branchwood biomass 22.7 t/ha and 7.9 t/ha respectively and green stem and branchwood biomass 53.3 t/ha and 18.4 t/ha respectively, the green agw being 71.7 t/ha, slightly more than the west Java, although the age of plantation was 1.5 years more than the Java. But the dry total agw biomass production (branches + twigs + wood + bark) of *A. auriculiformis* was only 17.1 t/ha and 34.6 t/ha in Bihar, India (Site: average rainfall 1500 mm, altitude 90 m good quality sandy loam soils up to the depth of 1 to 2 m) at the age of 7 and 9 years respectively (Wiersum and Ramlan, 1982). Dry above-ground wood biomass (agw, t/ha) produced by this species (Table 3) at Tarahara was found nearly two times than that of the wood biomass produced at 7 years, and slightly less than the agw production at 9 years. In contrast to the above figures, Sugur (1989) reported the green stem and branchwood (133.05 t/ha and 84.95 t/ha) including twigs of *A. auriculiformis* at spacings of 1x1 m and 2x2 m at the same site at 7 years. The higher production of *A. auriculiformis* at 1 x 1 m shows the way for research on various spacings to acquire optimum production. The green above-ground wood (agw) biomass (71.7 t/ha) of this species was similar to the above figure, since the data was 1.5 years earlier. With regard to stocking, it was found that the total yield is directly proportional to the number of plants per hectare (Kushalapa, 1987).

The wood production of these five species are comparatively lower than in those places where either full cultivation or full cultivation followed by intercropping is implemented for the first two to three years. Such cultivation is essential in private, community and government plantations for the enhancement of production in a short rotation. It can be concluded from the wood biomass of *A. catechu* that it could be included in any sort of plantations for firewood production. The feature of nitrogen fixation of *A. catechu* is more beneficial to *E. camaldulensis* in protecting the site from nutrient depletion. Although, *E. camaldulensis* , which had the highest wood biomass production, could not be ignored in small scale planting programmes.

These results would be useful for the Department of Forest, concerned institutions, and private tree growers for quantification of the wood biomass of these species in their plantations under short rotations.

Recommendations

- Further research is essential to investigate the optimum wood production of these species at different spacings.

- Planting of *Acacia auriculiformis* or *Acacia catechu* , nitrogen fixing species, should be done with *Eucalyptus* spp. alternately in the same site to maintain the fertility status of the site.

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