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IMPROVED MANAGEMENT OF IMPORTANT FODDER TREE SPECIES IN THE TARAI AND MIDDLE HILLS OF NEPAL

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Ten commonly grown fodder tree species of central and western Nepal were evaluated at four experimental sites between 1985-90. *Ficus semicordata*. *Bauhinia variegata*. and *Leucaena leucocephala* were found to be the top three high fodder yielding species. These species did well in all the four sites. All the growth attributes were significantly ($p=.01$) different among the species but were not so among the sites. Overall. Karmaiya (Plain) site gave the best height. diameter. and fodder growth followed by Hetauda. Rampur (Inner Valley) and Pokhara (Midhills) sites. A concurrent study conducted at farmer's fields indicated that the farmers' choice of species was governed both by propagational properties and milk yielding potentials of fodder trees. The three best performing (on-station) species were among the five of the most preferred and commonly grown fodder trees in central region of Nepal. The growth of on-farm trees also did not vary among the three sites evaluated. But they did vary among the species. The best propagation technique was through cuttings and planting plastic-bag raised seedlings. The nutritive values of the fodder trees were significantly different among the species but they did not vary across the sites. The dry matter content was highest in *Bauhinia sp.* and were lowest in *Morus alba*. In general. the highly preferred fodder trees growing on the farmer's field as well as those found in the forests were found to have high crude protein (CP). and low total ash (TA) contents. The results have indicated that some of the native fodder trees of Nepal if selected well and appropriately planted on the farmer's fields. have the potentials of improving the poor fodder stands which are commonly found throughout the Midhills today.

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Allometric regression equations were developed to predict foliage, wood, and total above ground biomass yield of two of the selected high yielding fodder tree species (FTS) - *Ficus semicordata*, and *Bauhinia variegata*. The data for these estimations came from the experimental plots and the farmer's field. Logarithmic transformations of dependent and independent variables gave the best estimates of dry foliage, dry wood, and total biomass on a single tree basis. Two different set of regressor variables were found to predict biomass for the two species. In case of *F. semicordata*, crown diameter and height gave the best fitting equation (r^2=81.6%). However, for *B. variegata*, diameter at 50 cm. (*db5*) explained most of the variation in component and total biomass (r^2=85.4%). First site specific models were developed for each of the four sites. Three of the sites were found to have similar slopes and intercepts. Therefore, all the four site specific data were pooled and a single model was developed based upon which fodder and wood tables were prepared for each of the two species. The information generated by these models and tables are expected to help solve some of the problem of lack of yield data in improving the management of fodder trees in Nepal. Some of these research results are already being applied by the farmers through cooperative research and extension programs launched through this Project.

IMPROVED MANAGEMENT OF IMPORTANT FODDER TREES IN THE TARAI AND MIDDLE HILLS OF NEAPL

Background

Nepal has one of the highest livestock populations per unit of cultivated land of any country in the World (DFAMS 1986). Estimated population of ruminants in 1990 was 15.66 million (m.) which comprised 6.3 m. cattle. 3.0 m. buffalo. 5.32 m. goats. 0.73 m. sheep. and 0.305 m. yaks. These figures are based on estimates by APROSC (1986).

In order to meet the increasing requirement of animal feed. farmers have been using tree fodder both from the forests and farmland: grasses. weeds. and shrubs from the forest: shrubs and grasses from the grazing and farm lands: crop residues extracted after harvesting of foodgrains: and roughage left over after human usages. Based on the standard annual feed requirements of about 1.032 metric tons per livestock unit (equivalent to an adult male buffalo). the annual feed requirements are estimated at about 6.387 million m. tons of TDN (total digestive nutrients). However. the estimated supply for 1990 was only about 6.0 million m. tons (APROSC 1986: MOFSC 1988). Of all the sources of animal feed. forests have been the most important one for centuries. However. due to uncontrolled cutting. grazing. burning. poaching. and conversion of the forests into agriculture land. fodder supply from the forests has been steadily decreasing. Currently forests contribute only about 17% of the total feed supply. Grazing lands which comprise about 12% of the country are the most degraded of all the land use types. The average production is estimated to be about 0.4 ton/ha and meet about 11.5% of total supply. Crop residues meet about 50% of the fodder needs but their quality is poor (Kafle and Karki 1988). The share of tree fodder has been continuously increasing and at present they are estimated to provide more than 10% of the supply. A recent study in central Nepal indicated that tree fodder both from the forests and farmland supplied about 30% of the total consumptions in two villages. Their potentials can be appreciated if we take into account of their multiple benefits such as supply of fodder. fuelwood. and food as well as conservation of soil and water resources. Besides. if grown properly. they can be compatible with food crops thus not competing with them for scarce land resources.

Although Nepal is endowed with a rich genetic diversity of fodder tree species. their full potentials have not yet been investigated let alone realized. Farmers have still been following traditional methods of managing fodder trees which in most cases involves protecting the natural regeneration in and around their homes and on the boundaries. walls and risers of their terraced lands. In recent years due to government sponsored programs. nursery raised seedlings are being supplied to the farmers and this practice is becoming popular. However. the emphasis has been only on increasing the number of trees rather than improving the productivity. This Project therefore took up the task of addressing the need for carrying out a comprehensive species evaluation and management improvement research. A total of sixteen different commonly grown fodder tree species (FTS) were included in a multiple location trials between 1985 and 1990 and and ten of them were evaluated for height. diameter. green biomass weight. and dry biomass weight. The research topic selected was one of the high priority topics listed by the recently completed Master Plan for Forestry Sector of Nepal (MOFSC 1988).

Several organizations supported the Project. Apart from my host institution - Institute of Forestry, Institute of Agriculture and Animal Science, Dept. of Livestock and Animal Health and several other agencies supported the Project.

Research objectives:

The Project had following research objectives:

1. **Main objectives:**
   a) to generate quantitative information about the present status of fodder tree cultivation with an emphasis on finding out yield, lopping method, lopping cycle, planting method and relationship of fodder trees with other socio-economic variables.

   b) to evolve a proper regeneration method of fodder trees for quicker and better tree growth as well as develop proper lopping cycle to ensure sustained renewability of the fodder resources.

2. **Secondary objectives:**
   a) to educate the farmers on the merits of better management of fodder trees

   b) to develop a method of properly integrating fodder trees cultivation with the other components of the farming systems.

   c) to extend an appropriate technology of fodder tree cultivation to the farmers.

Research methods:

Description of the research sites

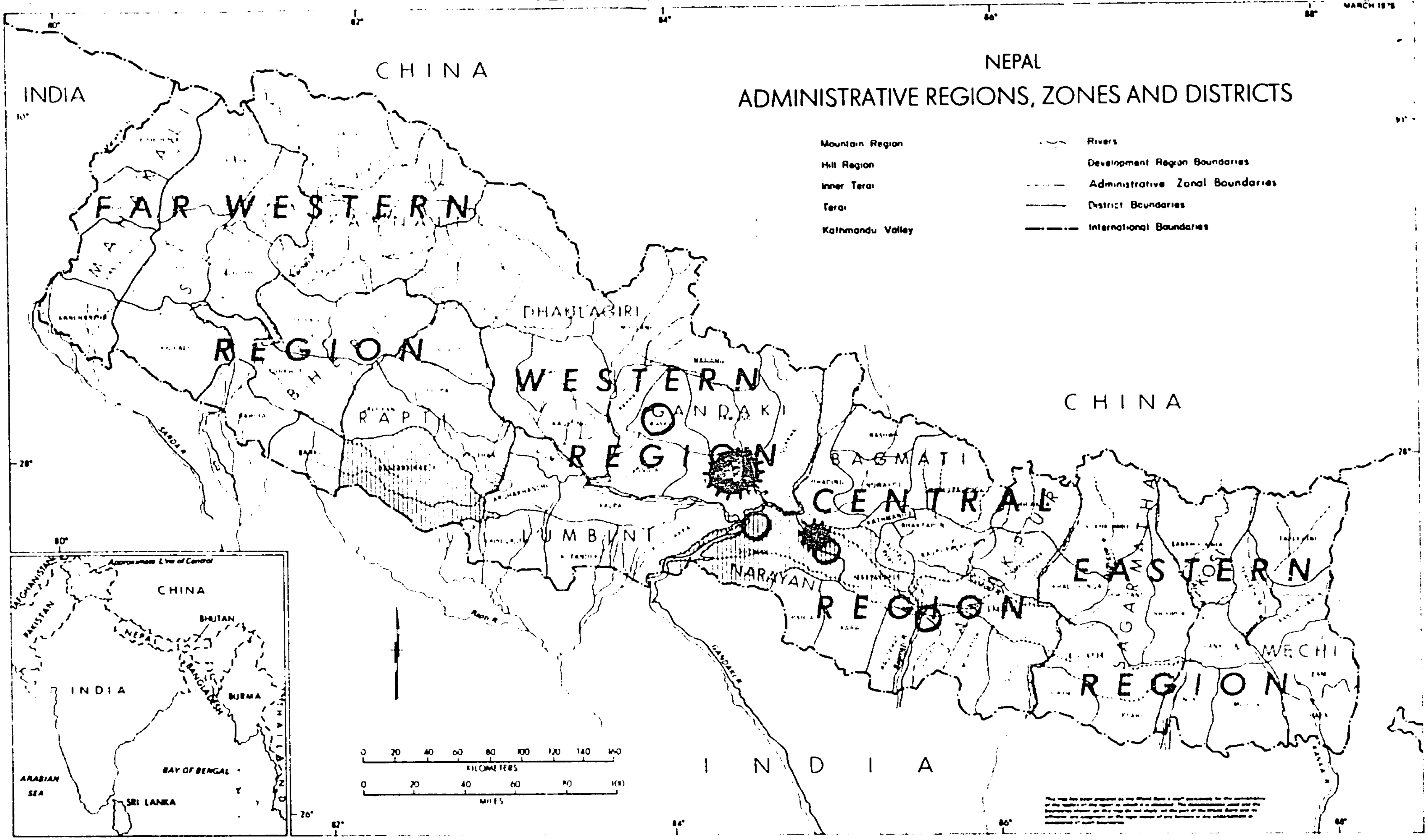
Five controlled (on-station) sites and three uncontrolled (on-farm) sites were selected from the three ecological zones (the Tarai, the Inner Tarai, and the Middle Hills) of Nepal (Figure 1). Climatically the sites were located within subtropical zone. Average annual temperature ranged between 20 to 24^{0}C and the average precipitation between 1869 to 3559 mm. The relative humidity was around 80%. Soils were coarse to loamy textured and were deficient in major nutrients. The PH values ranged between 6.2 to 8.3. The organic matter was less than 2%, and Nitrogen less than 0.5% (Table 1). Almost all the sites were abandoned agriculture or grazing land with gentle to flat slopes.

Table 1. Summary of climatic and soil information of four trial sites

Site	Av. temp. ^{0}C	Av. ppt. mm	Av. RH p.c	Soil PH -	Organic Carbon p.c.	Tot. N p.c
Karmaiya	23.68	1869.2	76.4	7.13	0.78	.07
Hetauda	22.68	2248.7	77.6	8.26	0.77	.06
Rampur	23.67	1990.9	81.8	6.44	1.61	.06
Pokhara*	20.46	3558.7	80.8	7.16	1.91	.14

* the figures are average of two sites

FIGURE - 1



◯ LOCATION OF ON STATION PLOTS

✹ LOCATION OF ON-FARM PLOTS

Map Source: World Bank, 1978

Species evaluation techniques:

Species selection techniques primarily for fodder producing trees are still in developmental stage. Therefore, the research designs used were similar to those applied to test multi-purpose tree species. Important variables which needed to be tested were: species, sites, height, diameter, green foliage weight, dry foliage weight and nutritive values. However, since the FTS also yield woody biomass and they are valuable as fuelwood, green and dry wood biomass were also important.

Experimental design

Since the objective of the trial was to assess the adaptability of the species in terms of their survival and vigor, the design chosen had to be properly randomized and replicated. The use of pure plot was inappropriate because the FTS were to be used within the mixed farming systems where trees are planted singly together with food and/or pasture crops (Stewart 1990). Provisions for testing the management interventions such as lopping or coppicing are also required in trials of such nature. However, in this trial the overriding design concern was how best to test the true potentials of each of the FTS included when grown on fallow and marginal farmlands of the Tarai and the Middle Hills of Nepal. Testing of lopping regimes although important was made secondary objective under this study.

Two types of experimental designs were used: Completely Randomized Block (CRBD) and Randomized Block Designs (RBD). The CRBDs were used at two sites (Karmaiya and Hetauda) where space was not limited and a gradient in site characteristics from one end to the another existed. The RBDs were used at three sites (Rampur, Pokhara 1 and Pokhara 2) where the space was limited and the sites were relatively uniform.

Assessment methodology

Most of the assessment methods used in the evaluation of fast growing multi-purpose tree species (MPTS) are based on height and diameter (Stewart 1990). However both of these measurements have problems. Height often is unsuitable for leaning and spreading trees which is the growth pattern common among the FTS. Diameter at breast height (Dbh) is also not suitable since the trees often are too young to develop a measurable Dbh. Therefore, in this study both vertical height and tree length as well as diameter at 30 cm (*db3*) and 50 cm (*db5*), were used as assessment criteria. Diameters were measured for each stem since almost all the trees were multi-stemmed ones. Yet another but the most important criteria of assessing FTS was the measurement of foliage and wood weight since these trees had to yield high foliage and wood biomass to meet the fodder and fuelwood needs of the farmers. Since no yield table data existed, both the green and oven dry weights were measured through destructive sampling.

Data collection

The data were collected using both non-destructive and destructive methods.

Non-destructive methods: Sampled trees were measured both at the experimental plots and at the farmer's field. Form A (see Appendix 1) was used to record both data types. Total height was measured as the vertical distance from the average groundline to the apical bud. Tree length was measured along the main stem from the groundline to the apical bud. The diameter was measured at the basal area, at 30 cm, and at 50 cm height depending upon the age. Diameter was inclusive of the bark. Each stem was treated individually when vertically separated at or below the 50 cm height of the main trunk. Phenology was recorded based on the stage of plant growth and development.

Destructive methods: Sampled trees were selected by height and diameter class and were felled from basal height. Tree lengths were measured as the distance from the groundline to the top of the measured stem along its actual alignment. Foliage inclusive of leaves, succulent branches, flowers, fruits and twigs were separated from the woody stems and branches and fresh wights were recorded using spring balance. Sample foliage and wood materials were collected and oven dried at 100^{0}C for 24 hours or until constant weight was reached.

Soil and climatic data were also recorded using sample collection in case of soils and using secondary sources in case of climatic data. The frequency of data recording was roughly once in a year.

Results:

The results include the performance of FTS included into the experimental trials and the management response of the trees which were located on the farmer's field.

On-station research trial results

Under this heading, the important results pertain to the survival of the seedlings, growth performance in terms of height, diameter, green foliage and wood weight, dry foliage and wood weight, foliage to wood ratio, and nutrient contents are discussed.

Survival percentage

The survival percentage of the ten species ranged between 72 to 84 percent. The difference was significant among the species but not so amongst the site (p=0.05). Table 2 summarizes the data:

Growth performance:

A. Height: Height was measured as the vertical distance from the base to the tip of the crown. To maintain uniformity only three year old height figures and only 10 species were compared. *Ficus semicordata* had the highest height growth followed by *L.leucocephala.* Species significantly (0.05) differed among themselves in height growth but the sites did not. The site with the highest organic matter content gave the highest height growth. Table 3 compares the height growth among the ten species.

Table 2. Survival percentage of the fodder tree species by site and species

Species	% Survival two years after planting by site					
	Karmaiya	Hetauda	Rampur	Pokhara1	Pokhara2[1]	Mean+/-SD
M. alba	76	54	95	40	96	72.2+/-24.8
L. monopetala	95	75	88	62	93	82.6+/-13.9
B. variegata	88	67	94	32	98	75.8+/-27.4
F. semicordata	92	73	95	54	98	82.4+/-18.6
B. purpurea	78	62	76	72	86	74.8+/- 8.8
F. auriculata	55	48	42	54	70	53.8+/-10.5
L. leucocephala	85	77	71	56	65	70.8+/-11.1
All Species	81.3	65.1	80.3	52.9	86.6	73.2+/-13.9

Table 3. Mean heights (m) and standard errors for three year old fodder trees at four sites in central and western, Nepal

Species	SITE Karmaiya mean	std.error	Hetauda mean	std.error	Rampur mean	std.error	Pokhara mean	std.error	All sites
M. alba	2.373	.503	2.180	.17	4.223	.659	3.017	.36	2.95
L. monopetala	1.807	.376	2.107	.37	2.590	.059	2.863	.415	2.34
B. variegata	3.193	.154	3.303	.061	5.557	.607	2.427	.073	3.62
F. semicordata	4.317	.450	4.457	.439	4.353	.525	5.880	.100	4.75
P. integrifolia	2.973	.227	1.230	.304	.	.	1.290	.278	1.83
B. purpurea	3.073	.251	2.880	.569	2.717	.206	.	.	2.89
F. auriculata	1.963	.297	2.233	.393	2.257	.107	2.830	.746	2.32
F. glaberrima	1.423	.294	1.243	.127	.	.	2.770	.210	1.81
A. lakoocha	2.220	.720	1.310	.108	1.347	.104	2.400	.150	1.82
L. leucocephala	4.303	.367	4.397	.323	6.210	.999	2.957	.319	4.47
All Sp. Mean	2.765		2.534		3.483		2.937		2.88
Std.error	.944		1.146		1.580		1.153		1.03

Diameter growth: Diameters were measured at basal area when they were three months old, at 30 cm. when two years old and 50 cm (*db5*) at three year. The last measurement indicated that *F. semicordata* had the highest *db5* growth followed by *B. variegata*. Once again the diameters were significantly different among the species but not so among the sites. Table 4 summarizes the diameter growth of the ten species at three years of age.

[1] This is the second site at Pokhara which was developed to supplement the poorly performing trial at the first site at the Institute of Forestry campus, Pokhara.

Table 4. Mean diameter at 50 cm (do5) and standard error of the fodder trees at four sites in central and western Nepal.

Species	Karmaiya mean	Karmaiya std.error	Hetauda mean	Hetauda std.error	Rampur mean	Rampur std.error	Pokhara mean	Pokhara std.error	All site mean
M. alba	3.153	.354	3.400	.386	7.880	.659	3.300	.700	4.44
L. monopetala	2.983	.534	4.677	.945	7.653	.183	5.740	.658	5.26
B. variegata	5.433	.511	6.900	.332	10.043	1.308	2.960	.269	6.33
F. semicordata	11.120	.911	9.717	1.483	10.203	.616	10.257	1.487	10.32
P. integrifolia	4.547	.369	2.667	1.320	-	-	1.757	.189	2.99
B. purpurea	3.587	.515	5.247	1.381	5.643	.552	-	-	4.83
F. auriculata	4.287	.624	5.400	.755	5.017	.829	3.857	1.158	4.64
F. glaberrima	2.693	.614	2.240	.114	-	-	3.653	.513	2.86
A. lakoocha	3.967	.951	2.877	.111	2.617	.183	5.307	.706	3.86
L. leucocephala	5.193	.574	7.657	.975	9.200	1.559	3.960	.092	6.50
All Sp. Mean	4.696		5.078		7.353		4.532		5.20
Std.dev.	2.434		2.434		2.507		2.452		2.06

Fodder and wood weight:

Since height and diameter alone were not the good indexes of judging the performance of fodder trees, fodder weight was used to evaluate their growth performance. Although the overall trend of species significantly differing and sites not doing so was continuing, the magnitude of difference among the species was more pronounced under these criteria. *L.leucocephala* was found to be closely following the top performing species *F.semicordata*. Multiple comparison carried out using Waller-Duncan Bayes LSD (BLSD) indicated that FS was significantly different from all other species. But LL was not significantly (0.05) different from *B.variegata* and *M. alba*.

Species ranking

Based on the above four criteria the species were ranked as shown in Table 5. *F.semicordata* and *L.leucocephala* were ranked first and second in all the four criteria used. However, these two species were significantly different in terms of their diameter at 50 cm. and foliage weight. In terms of their height and wood weight they were not significantly ($p=0.05$) different.

Comparisons of all possible means

Using BLSD method significant ($p=0.05$) differences between all the ten means were calculated. There was noticeable variation for each criteria of evaluation. For example, when using height and dry wood weight, FS, LL, and BV showed significant differences from all of the remaining species.

Table 5. Species ranking and their significance based on different criteria

Rank	Mean ht(m.)	Rank	Mean do5(cm)	Rank	folg.wt(kg)	Rank	wood weight
FS	4.75a	FS	10.32a	FS	4.89a	FS	9.86a
LL	4.47ab	LL	6.50b	LL	3.15b	LL	9.11a
BV	3.62abc	BV	6.33b	BV	1.87bc	BV	4.00b
MA	2.95cd	LM	5.26bc	MA	1.73bc	MA	3.40bc
BP	2.89cd	BP	4.83bcd	BP	1.30c	BP	2.86bcd
LM	2.34cd	FA	4.64bcd	FA	0.78c	PI	2.34bcd
FA	2.32d	MA	4.43bcd	LM	0.75c	FA	1.95bcd
PI	1.83d	AL	3.69cd	AL	0.59c	AL	0.95cd
AL	1.82d	PI	2.99d	PI	0.50c	LM	0.88cd
FG	1.81d	FG	2.86d	FG	0.51c	FG	0.71d
BLSD[1]	1.20		2.26		1.47		2.56

Means followed by the same letter are not significantly (k=100 or α=0.05) different. [1] stands for Waller and Duncan's Bays Least Significant Difference.

Notations: MA: *Morus alba*; FS: *Ficus semicordata*: BV: *Bauhinia variegata*: FA: *Ficus auriculata*; BP: *B. purpurea*; LL: *Leucaena leucocephala*; PI: *Premna integrifolia*; LM: *Litsea monopetala*; FG: *F. glaberrima*; AL: *Artocarpus lakoocha*.

However, when *do5* was used, FS alone indicated significant difference from all the remining nine species. The dry wood weight criterion made only FS and LL significant from the rest.

Results of on-farm trials:

Four species of fodder trees growing on farmers' field -*F.semicordta*, *L.monopetala*, *F.auriculata* and *A.lakoocha* were selected for undergoing four lopping interventions. The lopping regimes tested were: lopping 100% of crown height (CH): 75% CH lopping; 66.7%: CH lopping; and 50% CH lopping. The ANOVA indicated that the although the selected trees significantly (p=0.05) differed in their height and Dbh, the lopping intensity did not affect the total fodder and wood production. There was no significant difference (p=0.001) in the total fodder, total branchwood, and total biomass weight among the four treatments. This conforms to the farmers's argument that lopping induces foliage growth and lateral branching.

Nutritive values:

Collection of foliage samples from study sites and their chemical analysis indicated that dry matter (DM), organic matter (OM), crude protein (CP), and cellulose content were significantly different among species but the results indicated no such significant variations among sites. However, reverse was true for lignin. Highest % OM and CP were found in *L.monopetala*, and *A lakoocha*. *L. leucocephala* was also a rich fodder. The highly preferred trees as reported by the farmers tended to have high CP and OM percentage (Table 6).

Table 6. The nutrient contents of farmer's preferred fodder species

Rank[1]	Species	DM	OM	Cellulose	CP	Lignin
Best	*Litsea monopetala*	29.0	93.0	20.3	19.2	35.6
Best	*Artocarpus lakoocha*	29.0	91.4	28.3	20.3	21.6
Good	*Ficus hispida*	27.7	87.5	23.3	21.2	15.0
Good	*Ficus clavata*	36.8	88.6	26.7	16.2	12.6
Good	*Ficus lacor*	29.9	90.8	26.8	17.8	25.3
Good	*L. leucocephala*	34.4	91.8	25.8	18.7	28.1
Poor	*Ficus semicordata*	30.4	92.2	25.3	14.0	26.3
Poor	*Bridelia retusa*	36.8	91.4	26.8	10.3	17.2

[1] The ranking is based on the farmers' evaluation of foliage in terms of milk production response of lactating buffaloes.

In general, farmers' choice was found to be related to higher CP and OM contents. The preferred species also had low cellulose which is another indicator of good quality feed. Except for the *L.monopetala*, the preferred species also had low lignin content.

Growth and yield modeling

The current yield was predicted based on the measurement of height, *db5*, crown diameter, crown height, crown length, and tree length on the three to five year old experimental trees. Future yield was predicted based on the predicted allometric variables (Schlaegel 1983). Two types of models were suggested: local models based on the site specific data and general model based on the pooled data from the four experimental plots. Stratified random sampling method was used to collect the data and a total of 97 and 66 trees were destructively sampled in early 1991 for two FTS - *Ficus* and *Bauhinia* (Table 7). In order to account for the human impact on the growth of FTS, concurrent on-farm trials were set-up to test the impact of four different lopping intensities as measured by the length of the crown height lopped (chopping off foliage of the branches). The felled trees were separated into foliage, and totalwood (branch wood and stem wood) and weighed fresh. Oven dry weights were derived by drying the samples at 100^{0}C to a constant weight.

Table 7. Sampling distribution by diameter class in subject species

	Ficus semicordta				*Bauhinia variegata*				
Dia50cm cm	Pop. distribution No. of trees	%	Sample distribution No. of trees	%	diam 50 cm. class cm	Pop. distribution No. of trees	%	Sample distribution No. of trees	%
< 6.0	63	26.1	17	17.4	< 4.0	130	34.8	16	24.3
6.1- 8.0	54	22.4	22	22.7	4.1 - 5.0	41	11.0	5	7.6
8.1- 10.0	41	17.0	17	17.5	5.1 - 6.1	44	11.8	12	18.2
10.1- 14.0	50	20.8	24	25.0	6.1 - 8.0	64	17.2	16	24.2
> 14.0	33	13.7	17	17.4	8.1 -10.0	45	12.1	9	13.6
					>10.1	49	13.1	8	12.1
Total	241	100.0	97	100.0		373	100.0	66	100.0

Data analysis

Least square regression techniques were used to estimate the biomass. Following conceptual models were tested:

A general allometric relationship between two tree dimensions (x and y) was described by the following function:

$$y = ax^{b}e \qquad (1)$$

where a and b represented the intercept and slope of the model and e was called an error term or residual describing the part of variation in y which was not accounted for by x. Here x may represent diameter at 50 cm and y of course was the response variable.

For two predictor models, x_1 and x_2, the allometric equation took the following form:

$$y = ax_1^{b}x_2^{c}e \qquad (2)$$

where x_1 and x_2 may represent height and crown diameter and b and c their respective coefficients.

Both the equations (1) and (2) were converted to logarithmic forms making them linear as follows:

$$\ln(y) = a' + b\ln(x) + \ln(e) \qquad (3)$$

$$\ln(y) = a' + b\ln(x_1) + c\ln(x_2) + \ln(e) \qquad (4)$$

where a' = ln(a). Parameters a', b, and c of the linear form were computed through linear regression analysis and the ordinary least square methods. SYSTAT computer package was used to solve the equations.

Since the logarithmic transformation changes the distribution of residuals causing a slight underestimation in biomass prediction (Baskerville 1972; Sprugel 1983; and Pukkala *et al* 1990), correction factor given by (s.e.)*/2 was added to the equation, where s.e. is the standard error of the estimate. The base-10 s.e. was first converted into base *e* before using the value in the formula above (Sprugel 1983). The actual model that were used in the biomass prediction were therefore as given below:

$$\ln(y) = [a' + (s.e.)^{*}/2] + b\ln(x) \qquad (5)$$

$$\ln(y) = [a' + (s.e.)^{*}/2] + b\ln(x_1) + c\ln(x_2) \qquad (6)$$

Recommended Regression Models

The best fitting regression equations for the two FTS - *F.semicordta* and *B.variegata* contained two different sets of regressor variables. Crown diameter (cd) and height (ht.) predicted both the component and total biomass in the former (R^2=81.6) and *db5* did so (R^2=85.4) in the later (Table 8). Four (for four sites) foliage, wood, and total biomass models each were found to have the same regressors in the best fitting models for each species. Since the slopes and intercepts were found to be significantly not different (p=0.05) among the three out of four sites (Figure **2**), data were pooled and single models were developed for application for the two regions of Nepal. Prior to arriving at these models several candidate models were tested using tree length, crown height, crown length, crown ratio, and various combinations thereof. The criteria used to select the "best" models were: smallest values of RMS, fewest number of variables, smallest value of s^2, and smallest natural dispersion around the regression line as measured by coefficient of variation (Myers 1990; Draper and Smith 1981; and Hawkins 1987).

A host of climatic and soil variables were also tested in the process of model building. Average annual precipitation, average temperature, and % organic content were found to explain moderate amount of variations in the biomass variables.

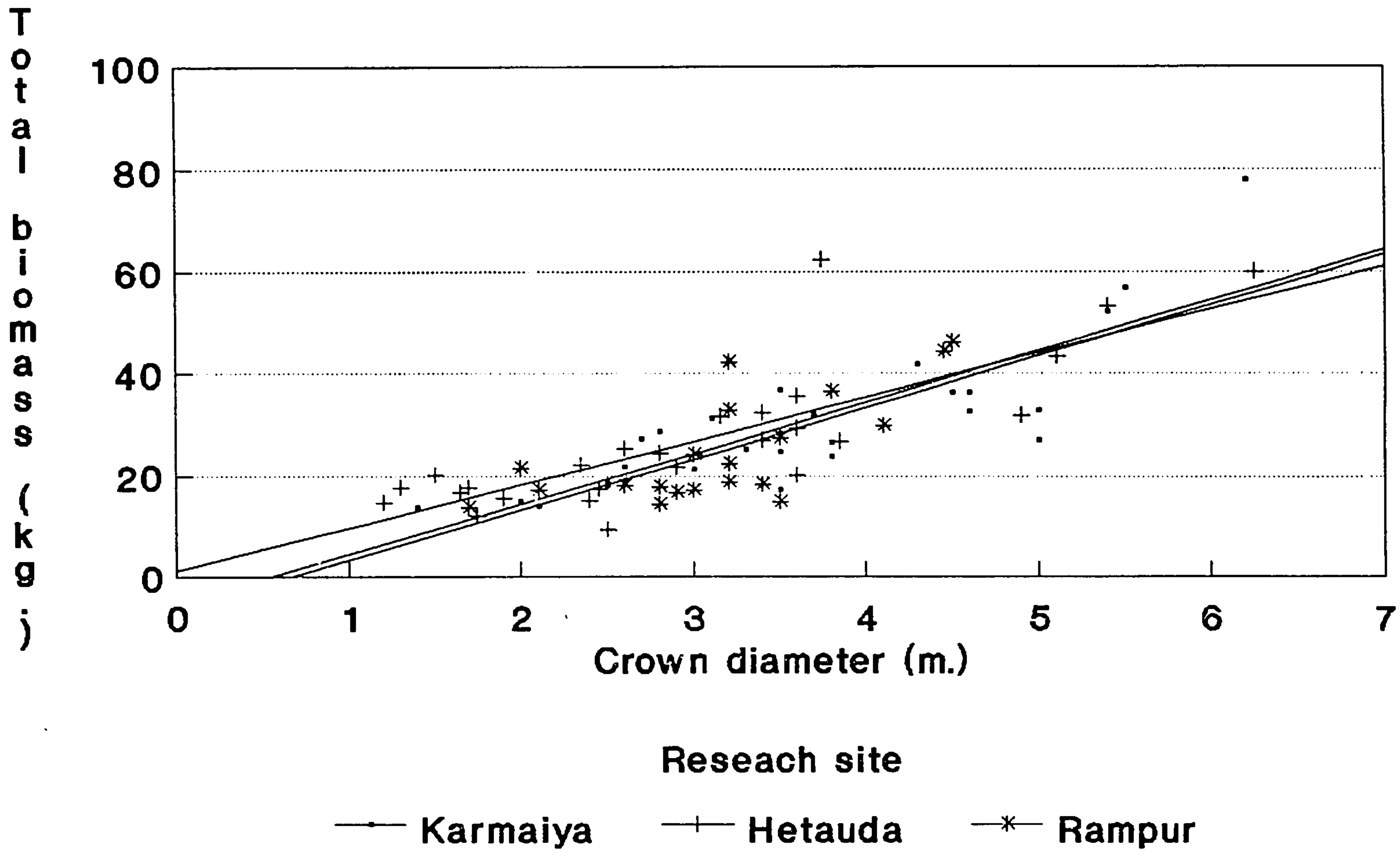
Residual analysis indicated that the errors were normally distributed, had uniform variance, and were uncorrelated to each other. The plots (Figure 3) of the residuals against the predicted value (y') and the predictor (x) did not show any pattern indicating biasness in the model structure. Outliers were detected but since their removal did not result in model improvement in *F.semicordata*, they were included in the final model suggested. In *B.variegata*, however, the removal of a single outlier improved the fit and therefore the final model excluded the outlier. The final models were validated using both the data splitting and independent data fitting techniques. In both the cases, the fitted models were found to be predicting the biomass within the 10 to 20 percent of the actual amount.

Since the regression slopes and intercepts for predicting total biomass were not significantly different among the three sites as shown above, common prediction equations for the two species were therefore presented in Table 8.

FIGURE - 2.1

CROWN DIAM. VS.TOT. BIOMASS RELATIONSHIP

Ficus_semicordata

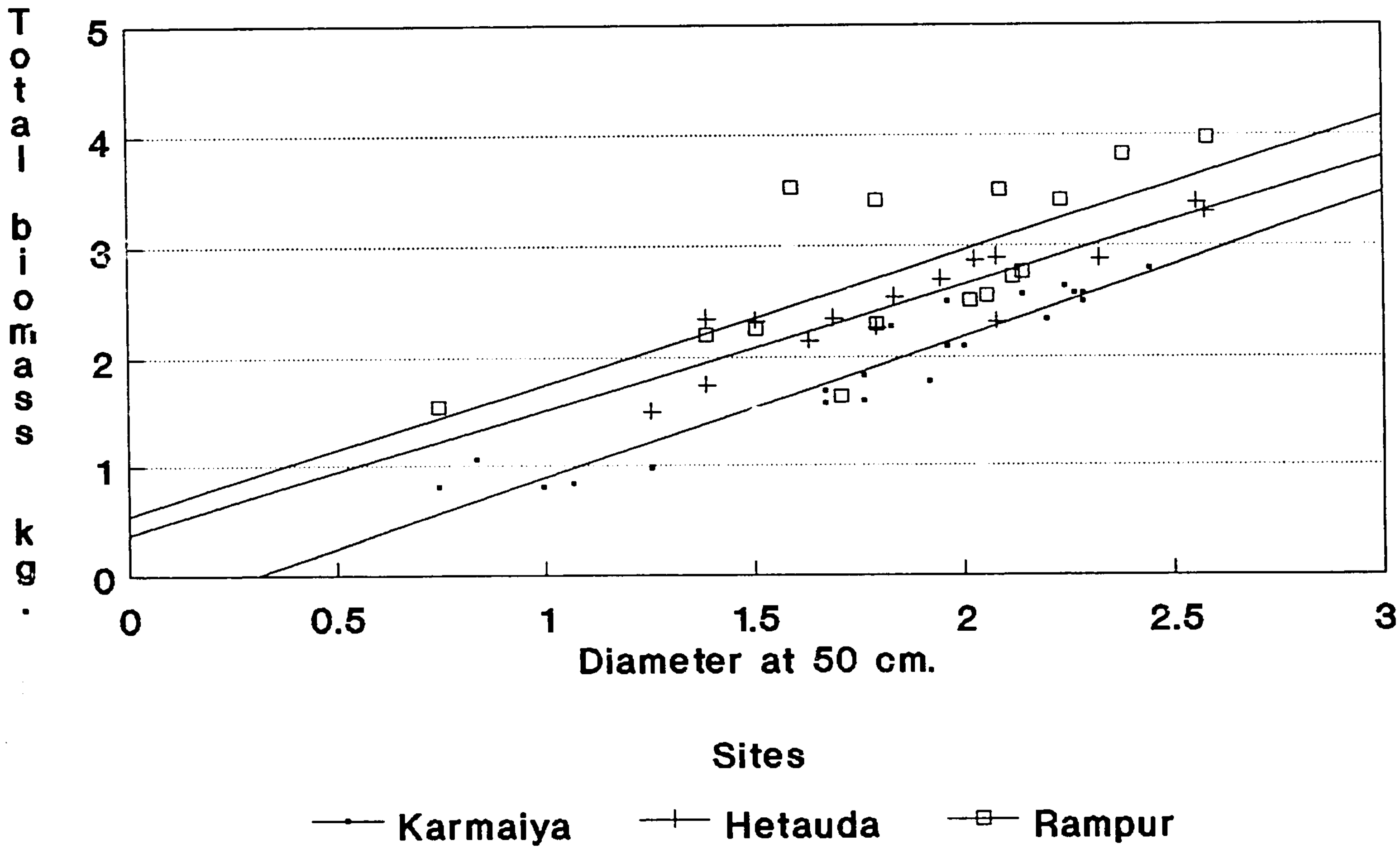


Oven dry weight foliage and total wood
1990 data

FIGURE - 2.2

DIAMETER AND TOTAL BIOMASS RELATIONSHIP

Bauhinia variegata



Logtransformed 1990 data

Figure 3.1 Plot of studentized residuals against estimated values in *Ficus semicordata* regression (total biomass) model

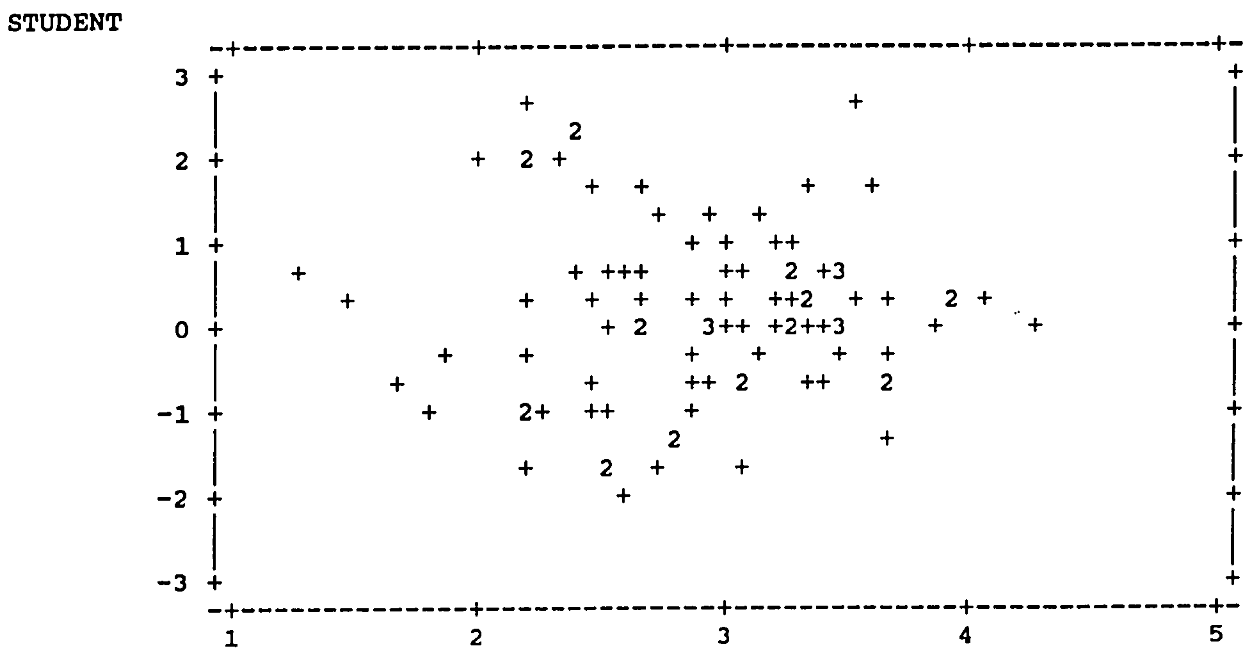


Figure 3.2 Plot of Cook's distance against the estimated values in Ficus model

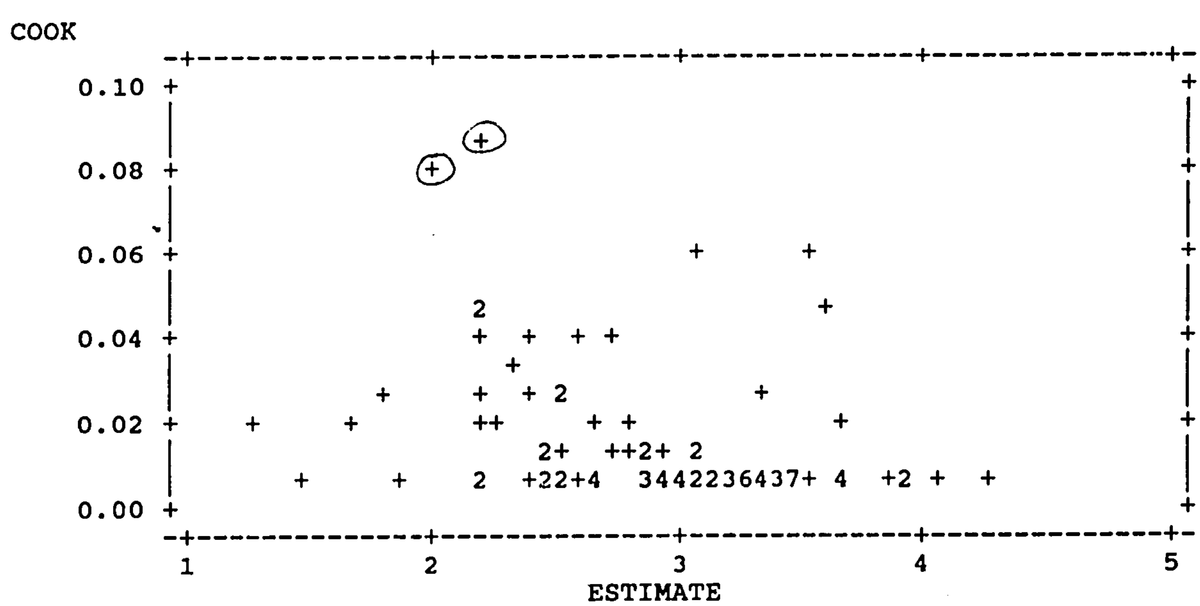


Table 8 . Prediccion equations[1] for the estimation[2] of foliage, totalwood and total biomass for *Ficus semicordata* and *Bauhinia variegata*

SITE/ Species	Foliage a	Foliage β_1	Foliage β_2	Foliage r^2	Foliage se	Totalwood a	Totalwood β_1	Totalwood β_2	Totalwood r^2	Totalwood se	Total biomass a	Total biomass β_1	Total biomass β_2	Total biomass r^2	Total biomass se	Sample characteristics: size n	Sample characteristics: range(do5 for BV, & height(m)forFS)
KARMAIYA																	
F.semicordata	0.899	0.853	0.321	.784	.191	.802	.851	.557	.751	.240	1.527	.846	.462	.786	.204	30	2.7-10.5
B.variegata	-1.247	1.114		.909	.185	-1.516	1.660		.948	.204	-.760	1.467		.946	.184	22	2.1-11.5
HETAUDA																	
F.semicordata	0.152	0.495	1.018	.800	.209	.389	.664	.927	.774	.254	.972	.590	.969	.809	.217	27	3.5-7.55
B.variegata	-0.813	1.098		.917	.134	-.367	1.308		.868	.207	.107	1.248		.894	.175	15	3.5-13.1
RAMPUR																	
F.semicordata	0.247	0.617	0.916	.813	.143	-.388	.867	1.352	.760	.242	.844	.641	.584	.836	.137	20	3.05-6.1
B.variegata	-1.045	1.004		.765	.304	-.489	1.300		.798	.359	-.044	1.220		.812	.322	15	2.1-16.1
POKHARA																	
F.semicordata	-0.039	0.702	0.690	.816	.163	.345	.578	.472	.762	.152	.571	.765	1.164	.839	.164	20	3.40-6.2
B.variegata	-0.993	0.968		.833	.215	-.628	1.089		.811	.261	-.106	1.047		.831	.234	14	1.85-7.8
ALL SITES																	
F.semicordata	0.489	0.977	0.461	.826	.250	.472	1.174	.491	.795	.277	1.165	1.086	.483	.824	.277	97	2.7-10.5
B.variegata	-1.126	1.100		.812	.269	-1.099	1.531		.830	.352	-.469	1.393		.843	.305	66	1.85-16.1

1 **Models:** $\ln Y = a + \beta \ln X^1$ for *Bauhinia variegata* and $\ln Y = a + \beta_1 \ln X^1 + \beta_2 \ln X^2$ for *Ficus semicordta*)
Notations: r^2 = squared multiple correlation coefficient; se = standard error of estimate; X^1 = diameter at 50 cm in centimeter (for *Bauhinia*) and crown diameter in meter (for *Ficus*); X^2 = height in meter; a = intercept; β_i = coefficients.

2 The correction factor is given by $\exp[(se*2.303)^2/2]$.

Yield predictions

Yield tables were prepared for the two species for which aforementioned models were developed. The present yield for *F. semicordata* was predicted based on the two types of models: The model using experimental data (Table 8) predicted yield for trees upto five year old and ones (Table 9) using the on-farm trees estimated yield for trees above five year old. Separate tables were prepared for foliage and wood biomass (Tables 8 and 9) since both of these products are used by the farmers for fodder and fuelwood respectively.

Table 9. Parameter estimates of allometric equations for validation models

Response variable	Predictor variable	Lna	β_1	β_2	SE	R^2	CF[a]	F
Ficus semicordata								
Total	crndiam/htm.	1.316	1.165	.634	.211	.861	1.1254	
Wood wt.	"	0.690	1.227	.645	.237	.843	1.1607	
Fodder wt.	"	0.565	1.102	.599	.240	.812	1.1651	
Bauhinia variegata								
Total	Dbh	-0.540	1.651		.168	.871	1.0777	
Wood wt.	"	-0.962	1.627		.165	.872	1.0749	
Fodder wt.	"	-1.583	1.684		.186	.852	1.0960	

[a] Correction factor was given by $\exp[(SE*2.303)^2/2]$

Table 10. Regional models for individual and total biomass estimation

Component	Models[1] *F. semicordata*	*B. variegata*
A: For trees up to 5 years of age (On-station models)		
Fodder	LnFw= 0.489+0.977*LnCd+.461*LnHt.	LnFw= -1.126+1.100*LnDo5
Totalwood	LnWw= 0.472+1.174*LnCd+.491*LnHt.	LnWw= -1.099+1.531*LnDo5
Total Biomass	LnTw= 1.165+1.086*LnCd+.483*LnHt.	LnTw= -0.469+1.393*LnDo5
B: For trees beyond 5 years of age (On-farm models)		
Fodder	LnFw= 0.565+1.102*LnCd+.599*LnHt.	LnFw= -1.583+1.684*Lndbh
Branchwood	LnWw= 0.690+1.227*LnCd+.649*LnHt.	LnWw= -0.962+1.627*Lndbh
Total	LnTw= 1.316+1.165*Lncd+.634*LnHt.	LnTw= -0.540+1.651*Lndbh

[1] The correction factor for conversion to arithmatic form is given by $\exp[(SE*2.303)^2/2]$; For SE values see Tables 8 and 9.

Notations: LnFw=Logtransformed Foliage Weight; Ww=Wood weight; Tw=Total Wt.

Discussion

The results have analyzed the common fodder species from some of the most important attributes used by the farmers to evaluate them. Three species - *Ficus semicordata*, *Leucaena leucocephala*, and *Bauhinia variegata* were found to be the best performing species. All the species were significantly (p=0.05) different in their growth characteristics at all the sites. This indicates that the FTS have an wide ecological range. For example *B. variegata* is known to grow between 150-2200 m. altitudinal range. However, the growth measures were not significant among the four sites in most of the species. This is not surprising since almost all the land available for planting in Nepal are marginal and abandoned farm or range land. This result is in line with common notion that without the site improvements, productivity can be increased if right type of species are selected. The height growth of the five year old trial species were significantly related to that of ten year-old on-farm trees of same species which indicated that young plantations can be used to predict future height and diameter for modeling purposes. This result also indicates the uniformity of sites in growth potentials. The indication that the soil and climatic variables were found to be related to the plant growth also indicate the importance of these two variables in representing sites. This result also points to a need to develop site indices for the FTS. The nutrient analysis conforms the overriding importance given to crude protein (CP) and soluble content by the farmers since fodder leaves are primarily fed to the lactating animals. However, since the species rich in CP are not often high yielding tree improvement through species selection needs to be carried out. In fact a large part of the current stock of trees growing on the farmer's field are poor in fodder yield. They should be gradually replaced by more productive native species which are available within the country.

Results described have indicated that foliage and woody biomass of the young fodder trees can be estimated through allometric regression equations. Screening of allometrical variables such as height, *db5*, crown diameter (cd), crown height, crown length, crown ratio; physical variables such as %organic matter, %silt/sand/clay, PH, and %N/P/K; and climatic variables such as average temperature/precipitation/relative humidity indicated that the allometric variables primarily height, *db5*, and cd were the superior predictors of both component and total biomass. Height and cd gave the best fit of the data for *F. semicordata* and *db5* provided the best prediction model for *B. variegata* - two high yielding and commonly grown fodder tree species of central and western Nepal. The site specific models for each of the above species were found to have similar intercepts and slopes. Therefore, a single model is valid for estimating fodder and wood biomass over range of sites and species in the central and western Nepal. The applicators are however, cautioned to apply these models without first validating these models. After all these models are still considered to be of primary in nature.

One of the other aspects of the results was the testing of hypotheses which were concerned about the questions which are often asked in biomass modeling. The null hypothesis stating height and *dbh* were the best predictors of biomass as is common in conventional forestry was rejected. In this study *db5* and CD were the best predictors. Crown dimensions were found to be reliable predictors of biomass in FTs with multiple stems and spreading growth forms. Biomass variation was not explained by the sites since the regression equations with site as a factor in the form of dummy variable was not significant (p=0.05).

Correct estimation of fodder and totalwood biomass is an important step for improving the traditional management of fodder trees in Nepal. The availability of widely applicable models can be useful in planning and developing community as well private forestry plantations. To this end the models described above will be useful both as the local and general models for two of the important FTS. The points to be emphasized as a guideline for future research is that a geographically generalized fodder and wood biomass estimation are feasible and more of such models should be developed.

Conclusions

The main thrust of this paper was to demonstrate that fodder trees common in the Middle Hills can be grown in the Inner Tarai and Tarai regions. The indication that few prominent species have shown similar or better growth in the Tarai than that recorded in the Hills is an encouraging result for expanding fodder cultivation in the Tarai areas as well. Establishment of a practical linkage between the on-station and on-farm research has been shown which is vital for agroforestry research works. The usefulness of nutrient analysis to understand the management goals of the farmers is also discussed. Overall, the study has attempted to carry out a comprehensive evaluation of FTS which was long overdue.

The predictors determined for the two FTS in this study can be applied to estimate fodder and wood biomass in central and western regions of Nepal within the limits of the tree age and tree size mentioned in the data. However, due to the widely varying physiographic and climatic conditions prevailing in these regions more such studies are needed to develop more accurate weight tables. Net-working among various agencies in carrying out uniform system of sampling is essential to minimize the cost and time for such efforts. As Crow (1983) recommended soil type, site index, tree age, range of diameters and heights, number of trees per hectare and land use history should be included in the data collected in order to compare the results. Silviculture or agroforestry systems of the FTS to be studied are important in the context of developing countries such as Nepal.

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APPENDIX

Table A1 Foliage biomass tables[b] for <u>Ficus semicordata</u> for the central and western Nepal[a] (single tree, oven dry weight in Kg.)

Crown Diam.(m)	Tree Height (m) 2	3	4	5	6	7	8	9	10	11	12	13
0.50	1.16	1.46	1.70	1.91								
0.75	1.68	2.10	2.45	2.77	3.06							
1.00	2.18	2.73	3.19	3.61	4.00	4.33	6.23					
1.25	2.68	3.35	3.92	4.42	4.89	5.32	7.97	8.55	9.11			
1.50	3.17	3.95	4.63	5.23	5.78	6.29	9.75	10.46	11.15	11.88		
1.75	3.65	4.55	5.33	6.02	6.65	7.24	11.55	12.40	13.20	13.98	14.73	
2.00	4.12	5.14	6.02	6.80	7.51	8.18	13.37	14.35	15.29	16.18	17.05	17.89
2.25	4.60	5.73	6.71	7.57	8.37	9.11	15.22	16.34	17.42	18.43	19.42	20.38
2.50	5.05	6.31	7.38	8.34	9.22	10.02	17.10	18.35	19.55	20.70	21.80	22.88
2.75	5.52	6.89	8.06	9.11	10.06	10.95	19.05	20.40	21.73	23.00	24.24	25.43
3.00	9.12	11.13	13.81	15.79	17.61	19.32	20.92	22.45	23.92	25.27	26.68	27.99
3.25	9.96	12.70	15.09	17.24	19.24	21.09	22.85	24.52	26.13	27.66	29.14	30.57
3.50	10.81	13.78	16.37	18.71	20.87	22.89	24.79	26.60	28.35	30.01	31.61	33.15
3.75	11.66	14.87	17.66	20.18	22.54	24.70	26.75	28.70	30.58	32.38	34.11	35.78
4.00	12.51	15.96	18.95	21.56	24.17	26.50	28.70	30.80	32.82	34.74	36.60	38.39
4.25	13.38	17.07	20.26	23.16	25.85	28.34	30.69	32.94	34.83	35.10	39.14	40.06
4.50	14.24	18.17	21.58	24.67	27.52	30.18	32.68	35.08	37.38	39.56	41.68	43.72
4.75	15.12	19.29	22.90	26.18	29.21	32.03	34.69	37.23	39.67	41.99	44.23	46.51
5.00	16.00	20.40	24.23	27.69	30.90	33.88	36.69	39.38	41.96	44.42	46.79	49.09
5.25	16.89	21.53	25.57	29.23	32.61	35.76	38.73	41.56	44.29	46.88	49.39	51.82
5.50	17.78	22.68	26.93	30.78	34.35	37.66	40.79	43.77	46.64	49.37	52.01	54.57
5.75	18.67	23.81	28.27	32.31	36.05	39.54	42.81	45.95	48.96	51.83	54.60	57.28
6.00	19.57	24.96	29.64	33.88	37.80	41.45	44.89	48.18	51.34	54.34	57.25	60.06

[a] This table has been prepared based on the sampling of two population data - within the height (ht.) range of 2-7.9 m and crown diameter (cd) range of 0.5-2.9 m. range the data were collected from the five year old experimental plots and model used was LnW=.378+.916Lncd+.547Lnht with a correction factor of .0238; and beyond these ranges the data came from the farmer's filed and the model used was LnW=.565+1.102Lncd+.599Lnht with a correction factor of .0192.

[b] Users are advised to validate the tables before using.

Table A2. Total wood biomass table for *Ficus semicordata* for the central and western Nepal[a]
(single tree, oven dry weight in Kg.)

Crown Diameter (m)	Tree Height (m) 2	3	4	5	6	7	8	9	10	11	12	13
0.50	1.11	1.33	1.52	1.67								
0.75	1.77	2.13	2.42	2.67	2.90							
1.00	2.47	2.96	3.37	3.72	4.04	4.32						
1.25	3.19	3.83	4.35	4.81	5.22	5.59	10.21					
1.50	3.94	4.73	5.37	5.94	6.44	6.90	12.78	13.79				
1.75	4.71	5.65	6.42	7.09	7.69	8.24	15.44	16.65	17.84			
2.00	5.49	6.58	7.48	8.26	8.97	9.61	18.17	19.61	21.00	22.32		
2.25	6.29	7.54	8.57	9.47	10.27	11.01	21.00	22.67	24.25	25.80	27.29	
2.50	7.10	8.51	9.67	10.69	11.60	12.42	23.89	25.78	27.61	29.35	31.05	32.69
2.75	7.92	9.50	10.80	11.93	12.95	13.88	26.88	29.01	31.05	33.02	34.92	36.77
3.00	12.23	15.89	19.13	22.09	24.85	27.45	29.91	32.27	34.56	36.74	38.86	40.92
3.25	13.49	17.54	21.10	24.36	27.42	30.28	33.00	35.60	38.12	40.53	42.87	45.14
3.50	14.78	19.20	23.11	26.68	30.02	33.16	36.13	38.99	41.74	44.38	46.94	49.43
3.75	16.08	20.90	25.15	29.04	32.67	36.09	39.32	42.43	45.43	48.30	51.10	53.80
4.00	17.40	22.61	27.20	31.41	35.34	39.04	42.53	45.90	49.14	52.25	55.26	58.34
4.25	18.75	24.32	29.32	33.85	38.09	42.07	45.84	49.47	52.96	56.31	59.56	62.72
4.50	20.11	26.13	31.44	36.30	40.85	45.12	49.16	53.05	56.80	60.39	63.87	67.26
4.75	21.49	27.92	33.60	38.79	43.65	48.21	52.53	56.68	60.69	64.53	68.25	71.87
5.00	22.87	29.72	35.76	41.29	46.47	51.32	55.86	60.34	64.61	68.69	72.65	76.50
5.25	24.29	31.56	37.98	43.86	49.35	54.51	59.39	64.08	68.61	72.95	77.16	81.25
5.50	25.73	33.43	40.23	46.46	52.27	57.74	62.91	67.88	72.68	77.28	81.74	86.06
5.75	27.16	35.29	42.46	49.03	55.17	60.94	66.40	71.65	76.72	81.57	86.27	90.84
6.00	28.63	37.20	44.77	51.69	58.17	64.24	70.00	75.54	80.87	85.99	90.95	95.77

[a] This table has been prepared based on the sampling of two population data - within the height (ht.) range of 2-7.9 m and crown diameter (cd) range of 0.5-2.9 m. range the data were from the experimental plots and the model used was LnW=.559+1.152Lncd+.447Lnht with a correction factor of .0354; and beyond these ranges the data came from trees selected from the farmer's field and model used was LnW=.690+1.227Lncd+.645Lnht with a correction factor of .0187.

[b] Users are advised to validate the tables before using.

Table - A3

FODDER TREE MANAGEMENT RESEARCH PROJECT

FORM A1: GENERAL TREE INVENTORY FORM

District: SARLAHI | Block No.: 1 | Plot No.: 1, 2 & 3
Trial Site: KARMAIYA | Date of Recording: 1/19 | Spp. Name: F. semicordata

Tree No.	Rep. No.	Block No.	Height (m.)	CRN DIA (cm.)	Aspect	Topogr-graphy	PH VAlue	Soil Texture	Phenology Codes	Remarks
1/1	1	1	5.7	3.3	S	F	6.4	LS	2	
1/3	1	1	5.2	5.0	S	F	6.3	LS	2	
1/1	2	1	3.85	2.0	S	F	6.4		2	
1/3	2	1	4.8	3.5	S	F	6.3		2	
1/1	3	1	5.0	3.8	S	F	6.3		2	
1/3	3	1	5.3	2.5	S	F	6.4		2	
1/2	4	1	4.2	2.1	S	F	6.3		2	
1/3	4	1	4.3	2.6	S	F	6.2		2	
1/1	5	1	3.7	3.0	S	F	6.3		2	
1/3	5	1	2.7	1.4	S	F	6.4		2	
1/1	6	1	5.5	2.5	S	F	6.5		2	
1/3	6	1	4.3	2.1	S	F	6.2		2	
1/1	7	1	4.3	3.8	S	F	6.4		2	
1/3	7	1	4.5	2.7	S	F	6.3		2	
1/1	8	1	4.2	2.6	S	F	6.3		2	
1/3	8	1	4.1	4.5	S	F	6.3		2	
1/2	9	1	3.6	5.4	S	F	6.2		3	
1/4	9	1	5.8	4.6	S	F	6.2		3	
1/1	10	1	10.5	6.2	S	F	6.0	L	3	
1/4	10	1	7.5	4.3	S	F	6.1	L	3	

AVAIL...