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O.F.I. OCCASIONAL PAPERS

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NO. 33

BIOMASS AND VOLUME TABLES FOR EUCALYPTUS CAMALDULENSIS, DALBERGIA SISSOO, ACACIA AURICULIFORMIS AND CASSIA SIAMEA IN THE CENTRAL BHABAR-TERAI OF NEPAL

by

Thomas Hawkins*

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OXFORD FORESTRY INSTITUTE
Department of Plant Sciences
UNIVERSITY OF OXFORD

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ISBN 0 85074 096 7
ISSN 0269-5790

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I. SUMMARY.

Single entry biomass tables of oven dry and fresh weight, based on the equation Ln Weight = a + b Ln DBH, (diameter at breast height) are presented for Eucalyptus camaldulensis Dehn., Dalbergia sissoo Roxb., and Acacia auriculiformis A. Cunn. ex Benth. Oven dry and green weight single entry tables are given for Cassia siamea Lam. using diameter at ground level (5 to 10 cm height) as the predictor variable. Single entry overbark and underbark total volume tables are given for E. camaldulensis and D. sissoo using DBH as the predictor variable.

The E. camaldulensis biomass and volume regressions were compared with two Eucalyptus tereticornis and two E. camaldulensis provenances. There was no significant difference between the equations of the four provenances for volume or stem biomass. The tables for all of the species have been validated for short rotation clean weeded plantations in the Bhabar-Terai region of Central Nepal.

The yield of the four species was estimated for different sites, ages, and spacings using the equations developed. E. camaldulensis and C. siamea are the most productive species with an oven dry fuelwood (stem and branch) MAI at age 4.5 and 2.5 years of 14 and 10 tons per ha respectively. E. camaldulensis, at the short rotation stocking of 10,000 stems per ha did not produce appreciably greater yields than a stocking of 2,500 stems per ha by age 1.5 years.

II. ABBREVIATIONS

A.D.B.	Asian Development Bank.
BD	Basal diameter.
CI	Confidence interval
C.S.I.R.O.	Commonwealth Scientific and Industrial Research Organization.
DBH	Diameter at breast height.
F.R.P.	UK-Nepal Forest Research Project.
F.S.R.O.	Forest Survey and Research Office.
H.M.G.N.	His Majesty's Government of Nepal.
Ln	Logarithm to base e.
N.A.F.P.	Nepal Australia Forestry Project.
OB Volume	Overbark volume.
O.D.A.	Overseas Development Administration.
O.F.I.	Oxford Forestry Institute.
S.F.D.P.	Sagarnath Forest Development Project.
UB Volume	Underbark volume.
V.S.O.	Voluntary Service Overseas.

III. ACKNOWLEDGEMENTS

I am grateful to the O.D.A. and the F.R.P. for the opportunity of working at the Oxford Forestry Institute. Thanks must also be given to the F.S.R.O., headed by E.R. Sharma, for enabling the data to be collected as part of the silvicultural research work. Many of the project staff, V.S.O's and H.M.G.N. foresters provided valuable discussion, advice and assistance. Ian Thompson encouraged me to look at forest yield from the biomass viewpoint, and he patiently answered my many questions on techniques and statistics. Most of the Adabhar data was collected with the help of F.S.R.O. rangers, in particular Bishwa Raj Shresta and Suroj Tamang. Ratna Kaji Shresta gave a great deal of help with collating the data and the determination of oven dry weights. Perhaps most rewarding was the opportunity of working with Shoba, the Adabhar forest guard, and the various Adabhar labourers. They tackled every task cheerfully despite the difficult work and poor living conditions, and taught me a great deal about the Bhabar forests.

A major portion of the work took place at the S.F.D.P. and would have been impossible without the help and warm hospitality of Kevin White. Discussions with Kevin invariably stimulated new ideas and approaches and were always a pleasure. The Sagarnath supervisor staff cheerfully and reliably measured and remeasured plots throughout the Terai heat. Graham Applegate, of N.A.F.P., collected the eucalyptus data set E1 and provided advice and assistance on biomass methodology.

At O.F.I. Howard Wright gave me useful support and guidance. Bernard Lobo wrote several computer programs to handle and store the data, and then taught me how to use them. Many other O.F.I. staff helped me to understand and use the computer and library facilities.

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BIOMASS AND VOLUME TABLES FOR EUCALYPTUS CAMALDULENSIS, DALBERGIA SISSOO, ACACIA AURICULIFORMIS AND CASSIA SIAMEA IN THE CENTRAL BHABAR-TERAI OF NEPAL.

1.0 INTRODUCTION.

In Nepal there is a very clear and well documented shortage of fuelwood (Pelinck et.al., 1984; Stewart, 1984) which affects everyone from the isolated hill farmer to the urban householder and the small scale industry. In the Terai region this firewood shortage is especially acute, and it is now common practice for farmers to burn manure and agricultural residue instead of using them to fertilize crops. The implications are clear: the provision of adequate supplies of reasonably priced fuelwood is essential in order to prevent the loss of local industry and to reduce the existing decline in agricultural productivity. During the last five years several forestry projects have been developed with the purpose of establishing high yielding short rotation fuelwood plantations to supply firewood to local industry and urban centres. Other community forestry projects aim to encourage Terai villagers to grow their own fuelwood and fodder trees on private and communal land.

Species, provenance and establishment trials carried out by the F.R.P. and the S.F.D.P. have identified the most promising species and establishment techniques for semi-industrial agroforestry plantations and smaller community woodlots (Hawkins, 1986; White, 1986). The two most important species are *E. camaldulensis* for fuelwood and *D. sissoo* (local name sissoo) for multipurpose private planting. Other promising species are *C. siamea*, *A. auriculiformis* and *Leucaena leucocephala* for multipurpose fodder, fuelwood and compost production. The correct planning and management of these plantations requires good estimates of growth and yield so that forest managers can make informed decisions about site selection, growth rates, agroforestry techniques and rotation length.

The purpose of this paper is to produce preliminary biomass and volume tables of the four most important Terai plantation species for use in estimating the early yield of short rotation plantations, and to measure the actual field precision and validity of the equations.

2.0 STUDY AREA.

The Bhabar-Terai zone is a strip of land 20 to 50 km wide extending along the southern border of Nepal. The altitude ranges from 100 to 300 m above sea level. The climate is subtropical, humid, summer monsoon with a four month rainy season starting in mid June. Rainfall is approximately 1,500 to 1,800 mm per year with 95% falling during the monsoon. Temperatures range from 42°C in the summer to 0°C in the winter, but frosts are uncommon.

The Bhabar is a zone of deep outwash sediments derived from the Siwalik hills to the north. The soils are an alluvial fan complex of 1 to 5° slope comprised mainly of sands and gravels deposited over the true erai soils to the south (Teare, 1986). Soil depth is variable and often shallow with a 20 to 30 m deep inaccessible water table. The soils usually have an impervious silty surface layer due to cattle grazing and annual fires. This reduces the infiltration of rainfall and causes rapid runoff and severe erosion. The combination of free draining soils, a deep water table and a seven month dry season produces an environment in which only drought hardy trees thrive. For these reasons the Bhabar zone is poor quality agricultural land and is often reserved for forestry and cattle grazing. The area is frequently dissected by braided streams which deposit eroded material over the Terai agricultural land to the south. These are deep silty loam soils with an accessible water table and are highly prized as farm land.

Agriculture is the major land use in the Terai. Large areas of forest have been cleared for conversion to crop production during the last thirty years. The staple crops are irrigated or rainfed rice, maize, mustard, millet and winter wheat. A variety of other cash crops such as sugar cane, tobacco, and jute are also grown.

The existing forests are old growth mixed hardwood forest comprised primarily of Shorea robusta (Sal) and Terminalia tomentosa (Asna) with mixtures of many other species. Cattle grazing and annual forest burning prevent natural regeneration, the annual increment is low, and in some heavily utilized forests is negative. Where these forests are located adjacent to communities they are extensively lopped for fodder and fuelwood. In other places the forests are felled to provide firewood for sale in Kathmandu and the Terai cities.

3.0 BIOMASS ESTIMATION TECHNIQUE.

3.1 Field data collection.

Data were collected at the F.R.P trial site at Adabhar and at the S.F.D.P. plantations over a two year period. Sampling was always carried out during the winter months between December and February when growth is slowest. For each species, undamaged sample trees were selected from the dominant and codominant crown classes to allocate a minimum of three to five trees per one cm DBH class across the full range of diameter classes available at that site. Suppressed or damaged trees were excluded from the sample as were trees of very poor form.

The sample trees were felled at a stump height of 5 to 10 cm using a bow saw. The predictor variable of total height was measured to $\pm$ 0.1 m and DBH and diameter at ground level were measured to $\pm$ 0.1 cm. The components of leaf, stem, and branch were separated and weighed to $\pm$ 0.01 kilos. Subsamples of each component were collected for the determination of moisture content and dry matter percent. These subsamples were weighed in the field and later dried in a forced air oven at 105^{o}C until a constant weight was reached. There was insufficient time to measure the dry matter percent of every tree sampled, therefore a mean dry matter percent based on five to ten trees was used to convert the data from green to oven dry weight.

3.2 Selection of biomass equations.

At the Oxford Forestry Institute the computer program VOLTAB was used to test fifteen equations to determine the best model to predict component weight. The statistics package MINITAB was used for data handling, plots, regression and residual analysis. The criteria used in selecting the equation of best fit included: the adjusted coefficient squared (r^2), the variance ratio from the analysis of variance (F), Furnival's index (Furnival, 1961), a normal distribution of the residuals when plotted against the predictor variable and the percent precision. The percent precision is defined as the the 95% confidence interval (CI) in kilos calculated as a percentage of the predicted weight ($\hat{Y}$), for the tree of mean DBH, ie, **(CI/$\hat{Y}$)x100**. This is a useful measure for the comparison of the precision of the equations between components and species.

For all four species the equation selected is **Ln Weight = a + b Ln X** which is the logarithmic transformation of the power equation **Weight = aX^b** . The X variable is either diameter at breast height (DBH, 1.3 m) or basal diameter (BD). Basal diameter is used in those species which do not produce a single clear stem, such as C. siamea or small size A. auriculiformis. It is measured as close to ground level as possible. In this case it is also defined as stump height, and measured at approximately 5 to 10 cm height. Figure 1 is a plot of Ln stem weight vs Ln DBH for E. camaldulensis, and Figure 2 is the residuals from this regression.

A disadvantage to the use of this equation is that the component predictions are not additive (Kozak, 1970). This means, for example, that the predicted weight of branch plus the predicted weight of stem may not equal the predicted value for stem and branch. To overcome this limitation equations are calculated for the individual components as well as for combinations of the components such as total fuelwood (stem and branch) or total tree weight.

Double entry tables including height as a predictor variable were tested and rejected because in Nepal the measurement of total height is time consuming and subject to large errors. The inclusion of height provided only a small increase in the precision of the regressions, but trebled the time required for the field inventory. It is essential that the tables are quick and simple to use, otherwise they are unlikely to be applied.

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). Sampling has to be carried out throughout the year to take account of seasonal variation in leaf production and retention. Site quality, spacing and between tree competition also affect the distribution and amount of foliage on the tree at a particular time. In this study no equations for the leaf yield of D. sissoo are calculated as most of the trees were leafless at the time of sampling. Leaf equations for C. siamea are excluded because there appears to be a strong relationship between leaf yield and stocking or spacing. There was insufficient time to examine this relationship more closely. Leaf equations are given for E. camaldulensis and A. auriculiformis but these must be validated before applying them on different sites or at any season other than the winter months.

Biomass equations are normally prepared on an oven dry weight basis to facilitate comparison with other sites, species and seasons. For this reason the main tables are given on an oven dry basis. However, fuelwood in Nepal is usually sold on a fresh weight basis with little or no storage period for the wood to air dry. In practical terms the forest manager needs to know the green or air dry weight of the crop as these are the merchantable units. Also it should be common practice to validate biomass tables before using them at new sites and spacings. For oven dry tables this validation requires felling the sample trees, then weighing and subsampling each component for dry matter percent. The necessary equipment

Figure 1. E. camaldulensis. Ln oven dry stem weight versus Ln DBH.

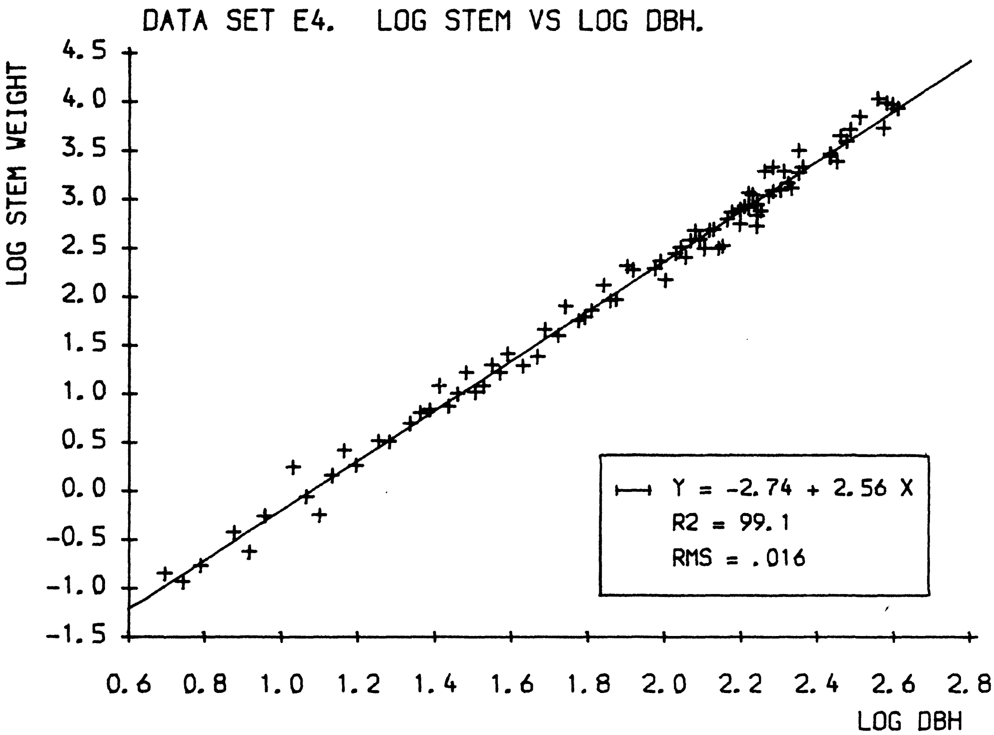
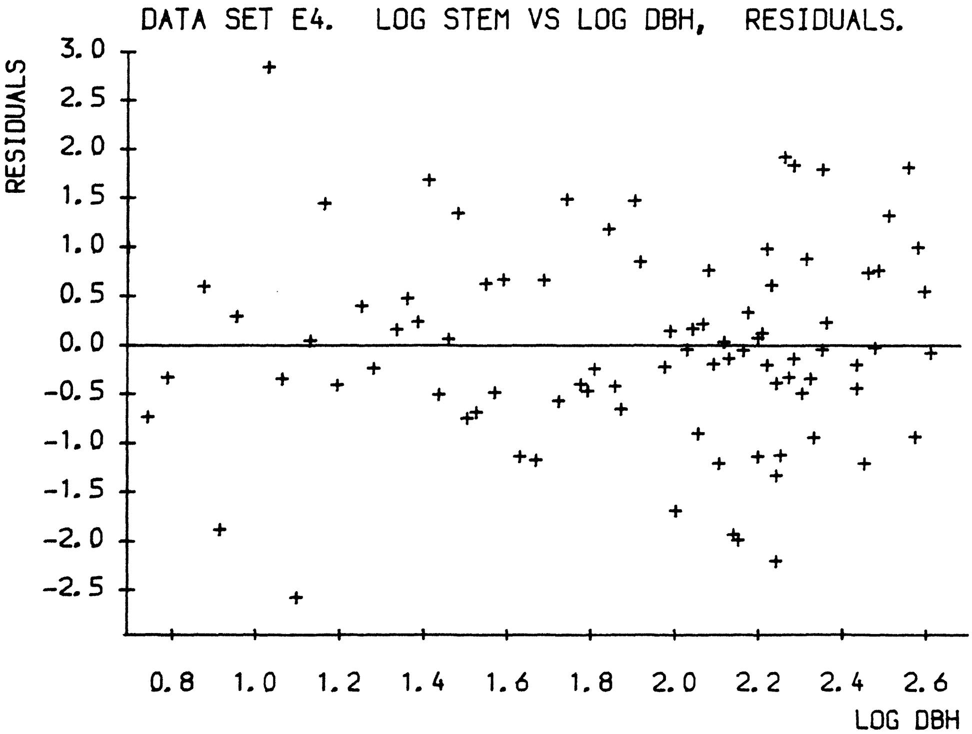


Figure 2. E. camaldulensis. Residuals of Ln stem weight versus Ln DBH regression



includes precise scales and an accurate forced air oven to determine the moisture content. In most field situations this equipment is unavailable and the technique impractical and time consuming. The validation of green weight tables only requires felling the tree and weighing the components using a normal spring balance. The provision of green weight tables is not a widely accepted practice, but these are of practical utility and are therefore presented in addition to the oven dry tables. The green weight regressions will be most reliable when trees are harvested during the winter months in order to minimize any possible error.

3.3 Validation of biomass equations.

The selected equations are checked by using at least one independent sample plot to test the predicted against the actual sample weights. The validation of biomass equations is a subjective procedure which is constrained by practical limitations on the number of samples available and the amount of time required. The method selected for this study is a statistical test followed by a more subjective assessment of the applicability of the equations.

In the validation plot a minimum of 15 trees are felled and the biomass recorded using the techniques described in section 3.1. The sample selected should cover the range of tree sizes which the biomass equations will be applied to in the actual field inventory. The first check is to calculate a regression of predicted weight against the actual weight and student's **t** test is used to test for slope equal to one and intercept equal to zero (see Figure 7). The determination of the practical validity of the equations requires plotting the percent error **[(actual weight - predicted weight/actual weight)x100]** against the predictor variable and visually checking for bias (see Figure 3). The main criterion, however, is that the sum of the predicted weights must be within 10 to 15% of the sum of the actual validation weights. All of the equations for stem and branch (fuelwood) and stem gave a predicted weight within 10 to 15% of the actual plot value, while leaf weight was more variable. There is no independent validation for the green weight equations as these only differ from the oven dry equations by a constant factor.

4.0 VOLUME ESTIMATION TECHNIQUES.

The selection of sample trees was designed to allocate 5 to 10 undamaged trees per 1 cm diameter class. The sample trees were felled using a bow saw at a stump height of 5 to 10 cm. After felling the tree the total height and DBH was measured. The stem was then marked into 1 or 2m sections, depending on the height of the tree. Overbark diameter and bark thickness were measured at each section to $\pm$ 0.1 cm accuracy. The maximum overbark top diameter was 1 to 2 cms. Total stem volume was calculated using Smalian's equation for eucalyptus. For sissoo Huber's equation was used for the first log and Smalian's equation for the subsequent logs.

The volume data was then plotted against DBH and height, and volume regression equations were tested and selected using the same criterion as biomass. The selected equation is **Ln Volume = a + b Ln DBH.** The correction for bias due to the log transformation (Baskerville, 1972) was tested and rejected as it only made a 1% improvement in the accuracy of the predictions. The volume equations were validated using the same techniques as for biomass.

5.0 EUCALYPTUS CAMALDULENSIS.
5.1 Biomass equations.

The E. camaldulensis biomass equations were initially developed from plantations at Sagarnath aged between 0.7 to 3.5 years. This is data set E1.

TABLE 1. Data Set E1.

	AGE IN YEARS	SPACING	LOCATION
Eucalyptus camaldulensis	0.7	4.0 x 1.7 m	Block 17A
Petford provenance.	1.5	2.5 x 2.5 m	Block 9B
	2.5	4.0 x 1.7 m	Block 6A
	3.5	2.5 x 2.5 m	Block 5A

Site preparation was similar at all four sites. Seedlings were planted into cultivated forest soil after full site discing. The plantations were maintained in a weed free condition by agricultural intercropping for a two year period. Trees were sampled according to the technique given in section 3.1 and oven dry weight equations were calculated for each component.

A separate randomized block provenance trial of E. camaldulensis and E. tereticornis was measured to compare the biomass equations between species and provenances. This trial, located at Sagarnath, was planted at a spacing of 1.4 x 1.4 m after the site was cleared and disced . At age 2.5 years old, two of the best E. camaldulensis and E. tereticornis provenances were sampled for volume and biomass. These provenances are from the CSIRO seed collections, and are included in other replicated provenance trials at Adabhar and Sagarnath. The provenances tested are;

CSIRO #	13476	Petford.	E. camaldulensis
CSIRO #	13801	Katherine.	E. camaldulensis
CSIRO #	12946	North Lakeland Downs.	E. tereticornis
CSIRO #	12947	Kennedy River.	E. tereticornis.

Fifteen to twenty sample trees from four replications were felled and the biomass was sampled according to the same techniques as data set E1. The dry matter percent for wood and leaf was calculated separately for each provenance. There was no significant difference between the dry matter percent of the four provenances at the 95% level. Therefore, a mean dry matter percent was calculated and used to convert all the provenance data from fresh to oven dry weights.

Regressions for the components of leaf, branch, stem, stem and branch, and total weight were calculated for each provenance using the equation **Ln Weight = a + b Ln DBH**. Regressions for the four provenances were then compared for common slope and intercept by ANOVA, using Dawkin's STATFORM 12 (1968). For the stem component, the regressions do not differ significantly in slope or intercept at the 95% level. This is the same result as the comparison of the overbark volume regressions for the four provenances. Comparison of the regressions for the components of branch, leaf, and stem and branch weight are unreliable as the residual mean squares of the respective regressions are not homogeneous. This is probably because the sample size of 15 to 20 trees per provenance is inadequate for the components with greatest variability, such as leaf and branch. As the stem regressions are statistically the same the data for the four provenances is pooled and used for the validation of data set E1. The pooled provenance data is called data set E2.

A second validation sample was collected from the Adabhar trial site, experiment number 28/84, to determine if the equations are valid for close spacing, short rotation plantations. This experiment is part of a replicated trial designed to measure the yield of three species planted at 1 x 1m spacing and harvested annually. The trial was planted after the site was burned and cleared, followed by ox ploughing in two directions to remove competing Imperata grass. Twenty cm tall seedlings were planted at the start of the monsoon and maintained in a weed free condition by hand cultivation of the soil twice a year. Data was collected in January at the first felling when the trees were 1.5 years old. Biomass equations for all of the components were calculated using the same techniques as the other validation samples. This is called data set E3.

Regressions of predicted stem weight versus actual stem weight were calculated for each data set, and the test for slope equals one and intercept equals zero applied. The prediction error for the validation plot, defined as
[(Σactual weights - Σpredicted weight/Σactual weights)x100] was calculated for each data set.

TABLE 2. Oven dry stem weight, E1 validation results.

	Plot prediction error	Student's t test, 95%
Data set E1 (Sagarnath four ages)	4% underestimate	slope ≠ 1, int. ≠ 0
Data set E2 (Pooled provenances)	4% overestimate	slope ≠ 1, int. ≠ 0
Data set E3 (Close spacing trial)	13% overestimate	slope ≠ 1, int. = 0

The validation analysis indicates that the three data sets are statistically different, although not greatly so. The plots of percent error vs DBH show bias in the prediction of data sets E2 and E3. The sample trees of data set E1 are not evenly distributed across the range of DBH, with inadequate sampling between DBH 2 and 5 cm. In order to develop a more even DBH distribution and improve the accuracy of the predictions the three data sets were pooled. Trees less than two cm in DBH were excluded as their measurement is often inaccurate. Data points were then randomly removed to retain approximately ten trees per DBH class with a limit of one tree per .1 cm class. This is called Data set E4. New regressions were then calculated for all of the components and the stem validation analysis recalculated. See Figure 1 for a plot of Ln stem weight versus Ln DBH and the residuals from this regression.

The regressions for data set E4 are increased in precision compared to data set E1 as measured by the regression analysis. The validation sample indicates an improvement in the prediction of all three data sets, with a reduction of the bias in data set E2 and E3. See Figure 3 for plots of percent error for each validation sample.

TABLE 3. Oven Dry Stem Weight, E4 Validation Results.

	Plot prediction error	Student's t test, 95%
Data set E1 (Sagarnath four ages)	4% underestimate	slope ≠ 1, int. ≠ 0
Data set E2 (Pooled provenances)	2% overestimate	slope ≠ 1, int. ≠ 0
Data set E3 (Close spacing trial)	5% overestimate	slope = 1, int. = 0
Data sets E1, E2, and E3 pooled.	1% underestimate	slope ≠ 1, int. ≠ 0

The *E. camaldulensis* biomass equations are therefore based on the pooled data set, No E4. Validation indicates that the new equations give an adequate prediction of fuelwood weight at the close spacing of 10,000 stems/ha as well as at the longer rotation stocking of 1,600 stems/ha. The validation of the other components follows the same pattern as stem weight, with decreasing accuracy for branch and leaf.

Figure 3a. E. camaldulensis Validation. Percent Error versus DBH.

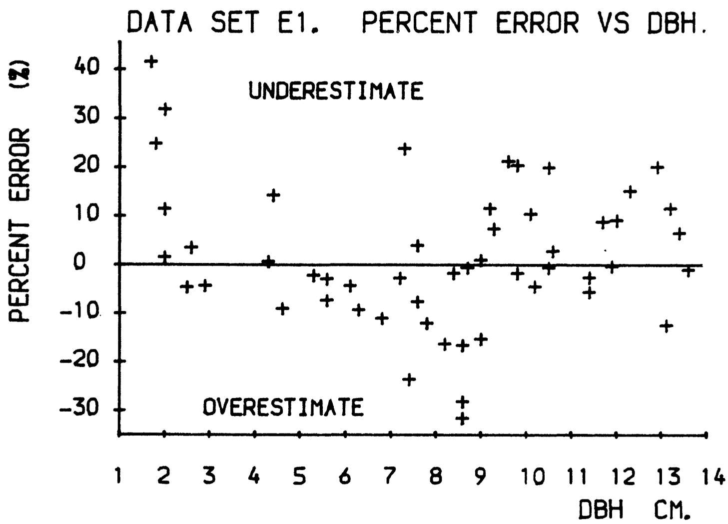


Figure 3b. E. camaldulensis Validation. Percent Error versus DBH.

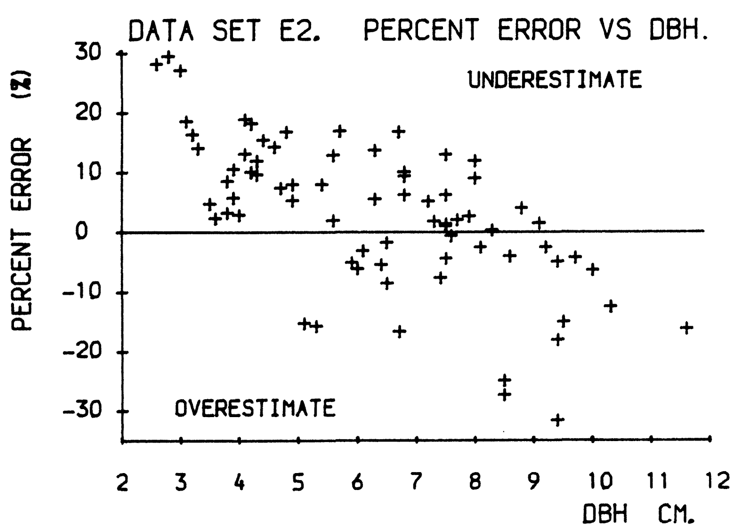
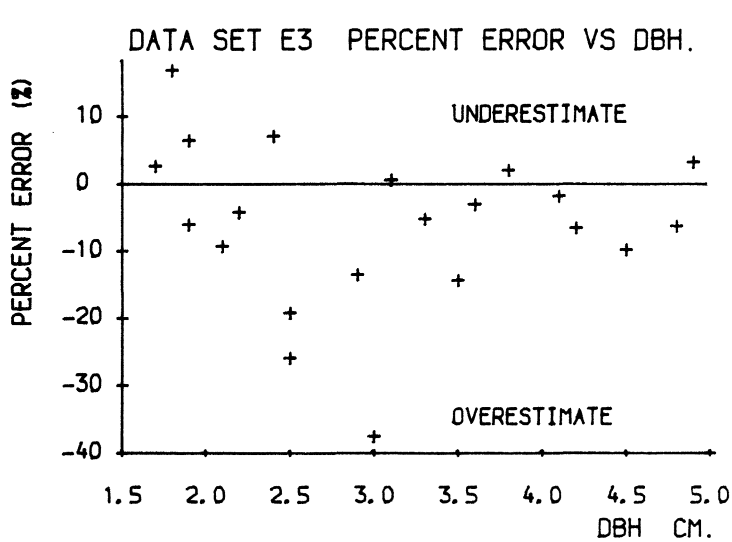


Figure 3c. E. camaldulensis Validation. Percent Error versus DBH.



The biomass equations calculated are clearly a compromise between the close and wide spacings. They are reasonably accurate for the present requirement of estimating yield with a ten percent accuracy. Analysis of the validation samples suggests that separate regressions for close and wide spacing will be more precise than the present equations. With the establishment of larger areas of fuelwood plantations in the Terai more data will be available from wider spacings, agroforestry plantations and coppice crops. As the new plantations develop it will be essential to revise these preliminary biomass tables for the wider range of forestry conditions experienced.

The equations are valid for the two provenances of *E. tereticornis* studied. It is likely that they are valid for other provenances of the same species provided the growth habits are similar. No test was made of the comparability of the regressions with the *E. tereticornis* seed source refered to as Mysore or Eucalyptus hybrid, as this has grown poorly in all the trials at Adabhar and Sagarnath and is very variable in form. It is unlikely that the biomass tables prepared from the Petford seed source will give reliable estimates of E. hybrid yield.

5.2 Wood density.

The basic wood density of *E. camaldulensis*, Petford provenance, was estimated by water displacement and oven drying for two ages and spacings. The first estimate is from a four year old plot planted at a spacing of 2.5 x 2.5m. Six samples of wood without bark were taken from the stem at a height of one meter. These had a basic density of 560 kilos/m . This is the same as reported by Tischler and Karschon (1983) from Israel. A second sample from the Petford provenance of data set E2 (age 2.5 years, 1.4 x 1.4m spacing) was used to estimate the density under short rotation management. Stem sections were taken from a height of one meter, none of the samples contained heartwood. With bark the basic density is 456 kilos/m , and without bark is 511 kilos/m .

5.3 Volume, overbark and underbark.

In the Terai eucalyptus is grown for fuelwood, which is marketed on a fresh weight basis. It is highly likely that some of these plantations will be managed as coppice with standards, with the coppice producing fuelwood on a 5 to 6 year rotation and the standards on a 10 to 12 year rotation for poles and construction timber. Many foresters still think of forest productivity in terms of cubic meters, and are unfamiliar with yield on a weight basis. The provision of comparable volume and weight tables will aid in the comprehension and conversion between the units. The preparation of biomass equations involves extensive field sampling and the additional time required to measure stem volume is slight. For these reasons volume tables are given here.

The volume equations were developed at Sagarnath from a 4.5 year old plantation of Petford provenance of *E. camaldulensis* planted at a spacing of 2.5 x 2.5m. Site preparation involved clearing the remnant forest followed by discing, then three month old seedlings were planted into the cultivated soil. Clean weeding was maintained for the first two years by agricultural intercropping. No fertilizers were used.

Each of the sample trees was felled and diameter overbark and bark thickness were measured at 1m intervals to a maximum top diameter of two cms. The volume equation: **Volume** = $[\pi L(d_1^2 + d_2^2)]/8$, (where d_1 and d_2 are the diameter at the bottom and top of the log in metres and L is the length of the log in metres) was used to calculate the volume for each section. The volume per section is then summed to give the total volume per tree.

A separate randomised block provenance trial of E. camaldulensis and E. tereticornis was measured to compare the volume equations between species and provenances and to validate the main table. Fifteen to twenty trees per provenance, from four replications, were felled and the volume measured using the same technique as the main volume table. A separate overbark volume equation was calculated for each provenance and the regressions for each provenance were compared using analysis of variance. There was no significant difference between the four regressions for slope or intercept at the 95% level, and the four regressions can be treated as one.

The data from the four regressions was then pooled to form a validation data set for comparison with the main volume regression. The predicted overbark volume was plotted against the actual overbark volume and a regression of predicted OB volume vs actual OB volume was calculated. Using student's **t** test, the slope is not significantly different from 1, nor the intercept different from 0 at the 95% level. The sum of the predicted volumes is a 6% underestimate of the actual volume, possibly due to the close spacing and age of the validation sample.

The plot of height versus diameter (see Figure 4) indicates a linear relationship up to DBH 12 cm and a decreasing rate of height increment between 12 and 17 cm DBH. On this site, with a rotation age of eight years, the top height at the time of felling will be between 20 and 25m.

Figure 4. E. camaldulensis Volume Data Set. Total Height versus DBH.

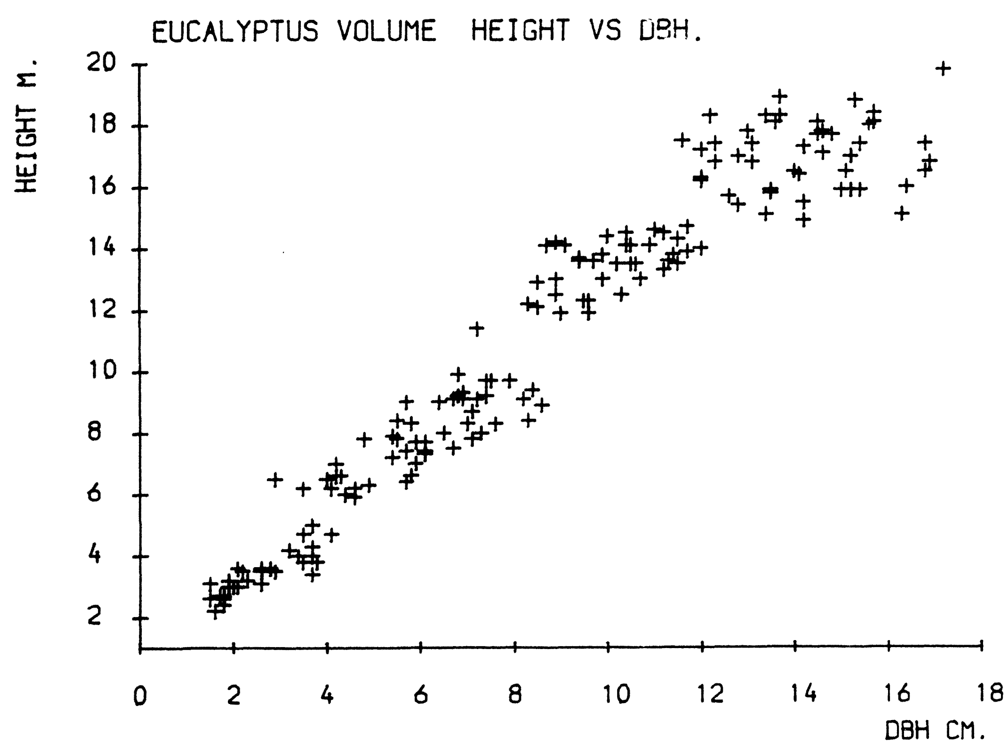
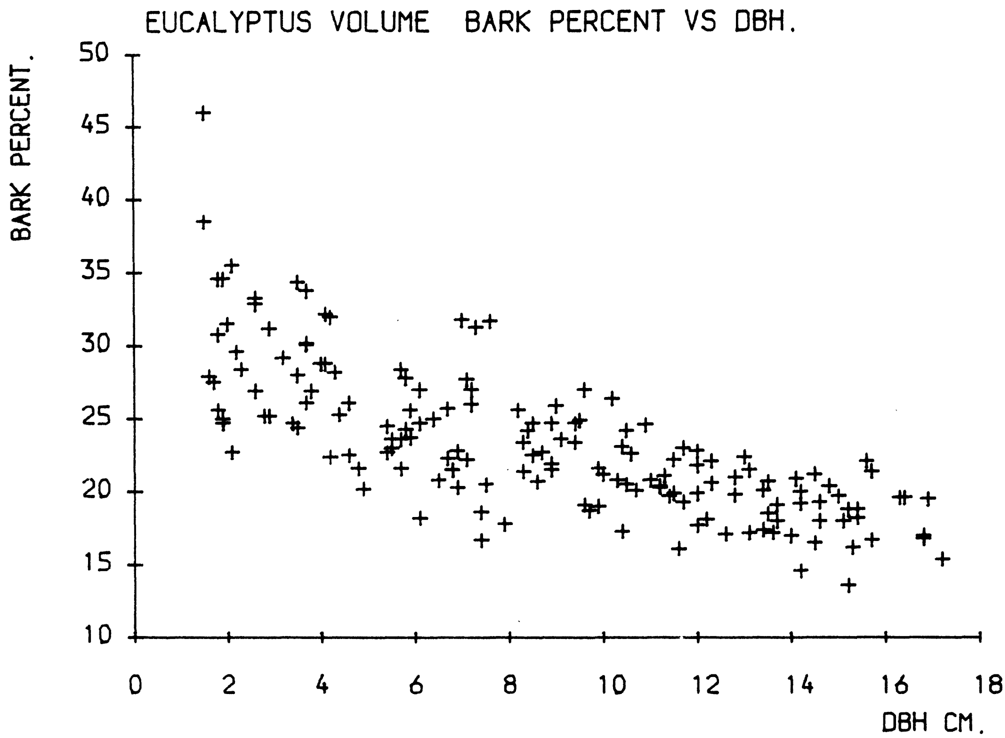


Figure 5, a plot of bark percent vs DBH shows that bark percent declines from approximately 30% at 3 cm DBH to 20% by DBH 17 cm. Bark has a lower calorific value than wood (Tischler and Karschon, 1983) and produces more ash when burned. Because there is no extra labour involved in splitting, the very small diameter wood makes an acceptable household fuel since the traditional stove design restricts the use of large wood. The build-up of ash in household stoves is not a problem as it is used for a variety of purposes, including spreading on the fields as a fertilizer. Wood of a diameter between 15 and 20 cms will produce a hotter fuel with less ash accumulation and is more appropriate for tobacco curing and brick or tile kilns.

Figure 5. E. camaldulensis Volume Data Set. Bark Percent versus DBH.
Bark percent = (OB volume - UB volume/OB volume)x100



6.0 DALBERGIA SISSOO.
6.1 Biomass equations.

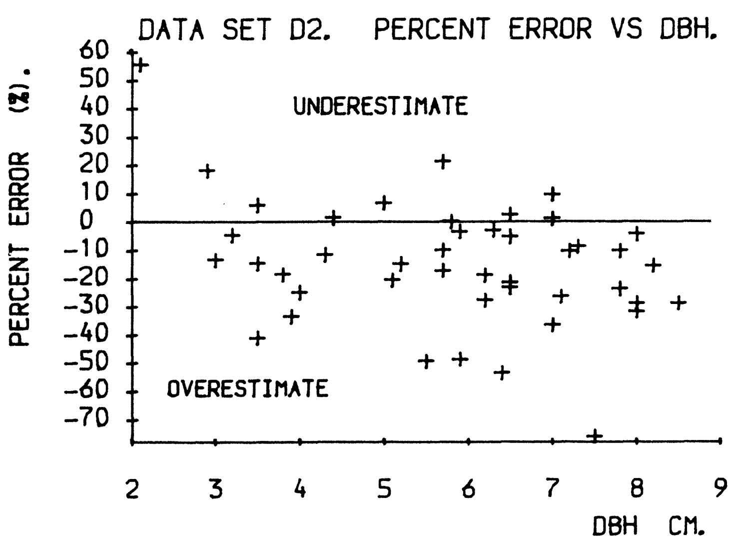
In the Terai region sissoo is a true multipurpose tree, and is the villagers preferred species for private planting. Its primary end use is for high quality saw timber for furniture making and local construction. It can be lopped twice each year for cattle fodder and the small branches are used as firewood. Compatible volume and biomass tables have been calculated to provide yield estimates for small size timber and fuelwood.

The sissoo biomass and volume equations are calculated from the same data set, called D1. A sample of 42 trees was selected from four blocks of the Sagarnath plantations to allocate two to three trees per each one cm DBH class. The trees were between 2 and 11 years old and were planted at a spacing of 2 x 2m or 2 x 4m. The land was prepared by full soil cultivation and one year old stump cuttings, or four month old seedlings were planted into prepared pits. Weed growth was controlled for the first two years of the plantation, either by agricultural intercrops or by hand weeding 1m diameter pits. Good growth was only achieved on soils with an accessible water table (White, 1986).

Oven dry and green weight tables based on the equation **Ln Weight = a + b Ln DBH** are given in Appendix A. The requirement for the inclusion of height as a predictor variable was tested by comparison of the selected equations with equations of the form **Ln Weight = a + b Ln DBH + Ln Height.** For the oven dry stem weight equations the addition of height improved the r^2 by a statistically significant amount at the 95% level. This, however, was of no biological significance as it only accounted for 0.7% of the unexplained variation, increasing the r^2 from 98.8 to 99.5. The same situation occurred for the components of branch, and stem and branch.

Two independent samples were used for the validation of the equations. The first, D2, is a sample of 43 trees planted at a spacing of 2 x 2m at the Adabhar trial site. The trees were age 2.5 years old at the time of sampling. For the test of predicted versus actual stem and branch weight, the intercept equals 0, but the slope does not equal 1. The sum of the predicted weights is a 15.5% overestimate of the actual plot weight. The plot of percent error versus DBH (see Figure 6) shows a consistent overestimate across the range of DBH sampled, however there is no clear bias. This is a large overestimation, and could be due to site differences between Sagarnath and Adabhar. The trees in this validation sample were damaged by monkeys at an early age and might have developed excessive branchiness as a result.

<u>Figure 6</u>. <u>D. sissoo</u> oven dry stem and branch weight validation.



The second validation sample, called D3, is from experiment 28/84 at Adabhar. The trees were planted at 1 x 1m spacing and felled at age 1.5 years. The sample size is 34 trees. The regression of predicted stem weight versus actual has a slope of 1 and the intercept is equal to 0 (see Figure 7). The sum of the predicted stem weights is a 6.1% overestimate of the actual plot weight. However, the plot of percent error versus DBH (see Figure 8) indicates a tendency to overestimate the trees less than 2 cm DBH and to underestimate for trees greater than 4 cm. This is of some concern, and indicates that it may be necessary to develop separate tables for close spacing, short rotation plantations. For the present time the tables presented give an adequate estimate of the production.

Figure 7. D. sissoo oven dry stem validation, regression of predicted versus actual stem weight.

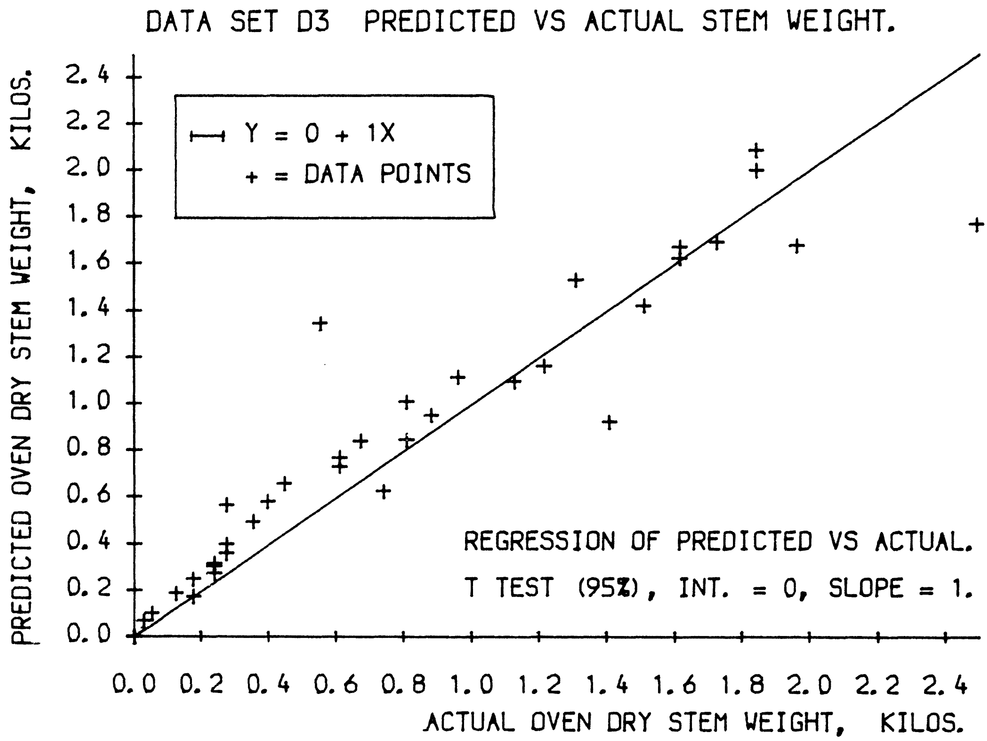
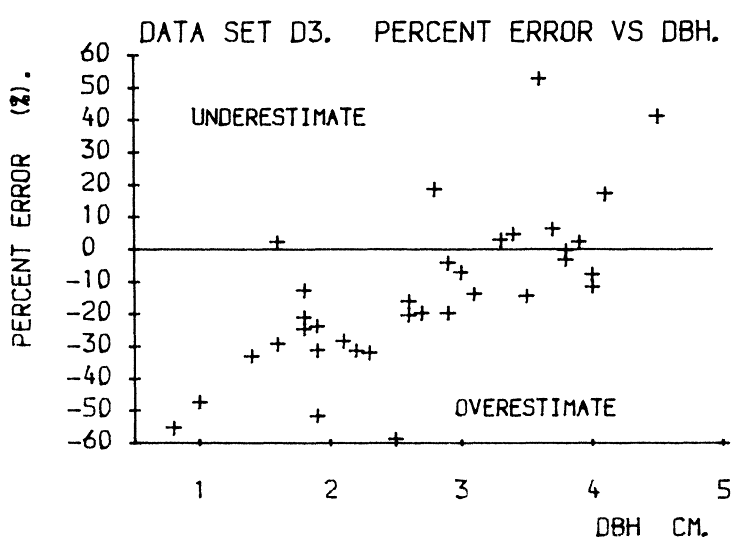


Figure 8. D. sissoo oven dry stem weight validation.



6.2 Wood density.

The basic wood density of sissoo with and without heartwood was estimated by water displacement. The density of five samples containing heartwood from trees age 10 to 11 years was 536 kilos/m^3. A second sample of stem wood was taken from five trees aged 1.5 years old growing at 1 x 1m spacing. These stem sections contained only sapwood, and had a basic density of 510 kilos/m^3. Sissoo does not begin to develop substantial amounts of heartwood until age eight to ten years or older. For most short rotation fuelwood plantations heartwood will not occur.

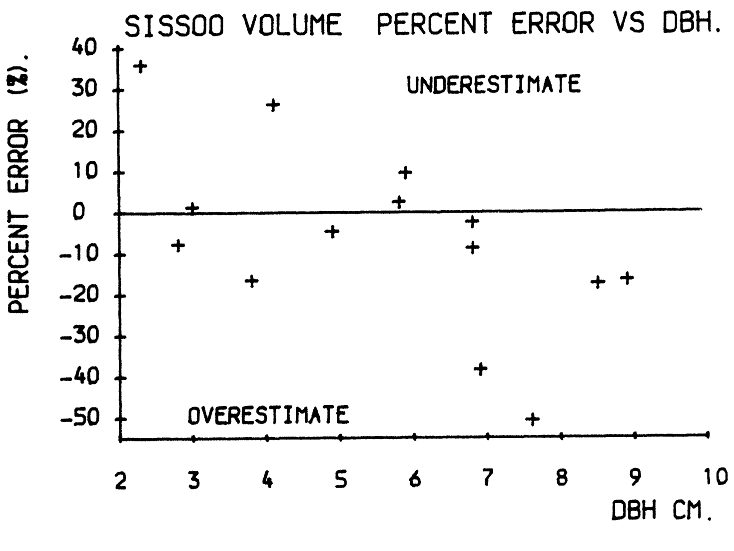
6.3 Volume, overbark and underbark.

Sissoo is primarily used as a timber species due to the high value of the wood for cabinet work. There is a possibility that some of the existing fuelwood plantations of sissoo will be converted to timber production and managed on long rotations either as coppice with standards or thinned to wide spacing for timber production. The volume tables produced here are not designed for such long rotation timber stands; they are merely to be used for predicting the total volume production of the existing stands of sissoo planted at normal spacing for fuelwood.

The volume equations were developed using the same sample as the sissoo biomass. The trees were measured, according to the technique described in section 4.0, to a top diameter of 2 cm. Volume of the first 2m log was calculated using Huber's formula, **Volume** = $\pi LD^2/4$, where D is the diameter at the midpoint of the log and L is the length of the log in metres. The volume of the subsequent 1m sections was then calculated using Smalian's equation and the volume summed to give the total volume per tree. The calculated overbark and underbark equations are given in Appendix A.

Validation of the volume tables was calculated using one sample of 2.5 year old sissoo planted at Adabhar at a spacing of 2 x 2m. For the regression of predicted OB volume versus actual OB volume the slope does not equal one but the intercept does equal zero. The total predicted OB volume is a 12.3% overestimate of the actual plot OB volume. The plot of percent error versus DBH shows a tendency to overestimate trees greater than 7 cm DBH (see Figure 9). The predicted underbark volume does not differ significantly from the actual underbark volume using any of the test criteria.

Figure 9. D. sissoo overbark volume validation, percent error versus DBH.



The plot of height versus DBH (see Figure 10) shows a linear relationship up to DBH 18 cm. The plot of bark percent versus DBH does not indicate a strong trend towards decreasing bark percent with increasing DBH (See Figure 11). Bark percent varies from 35 to 20% across the DBH sample.

Figure 10. D. sissoo Total height versus DBH.

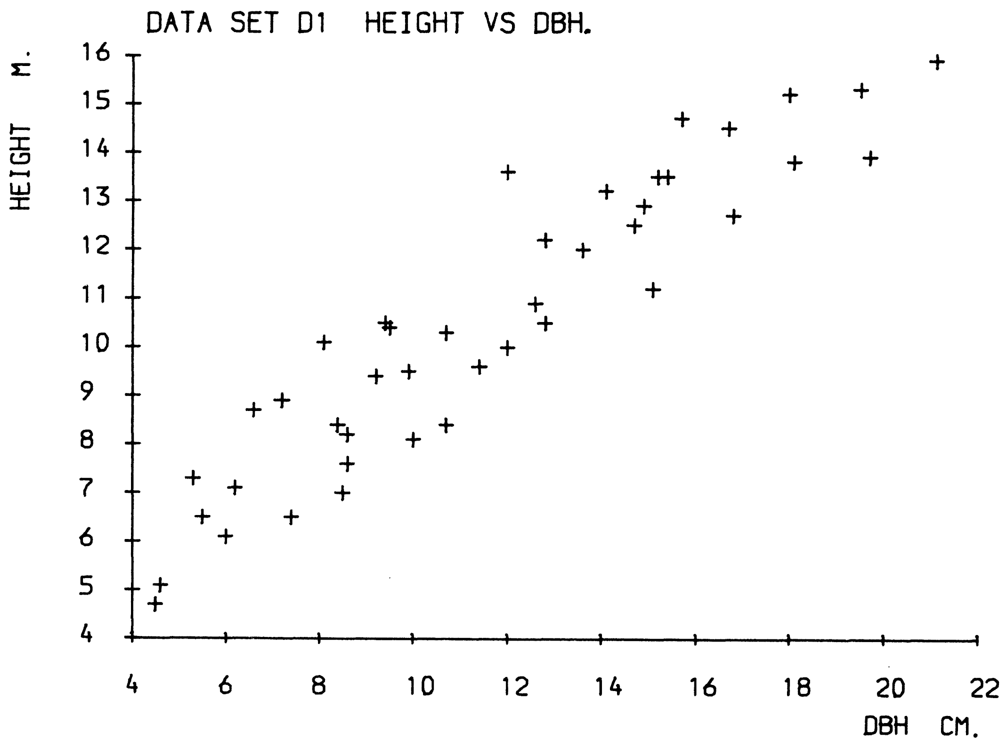
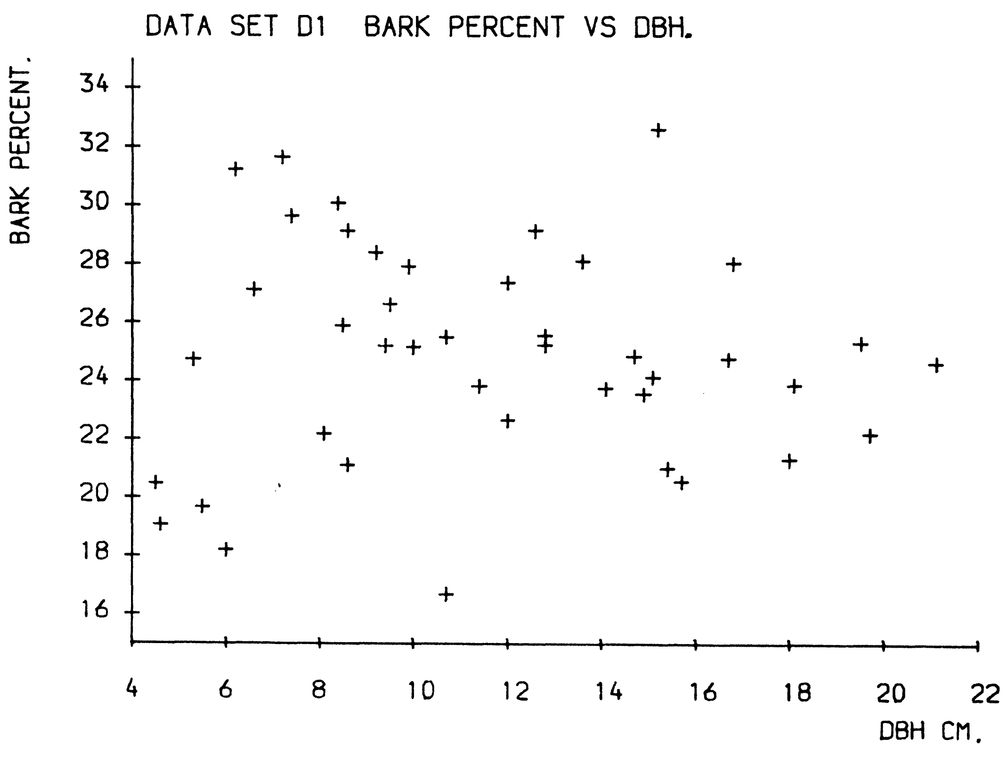


Figure 11. D. sissoo Bark percent versus DBH.



7.0 ACACIA AURICULIFORMIS.

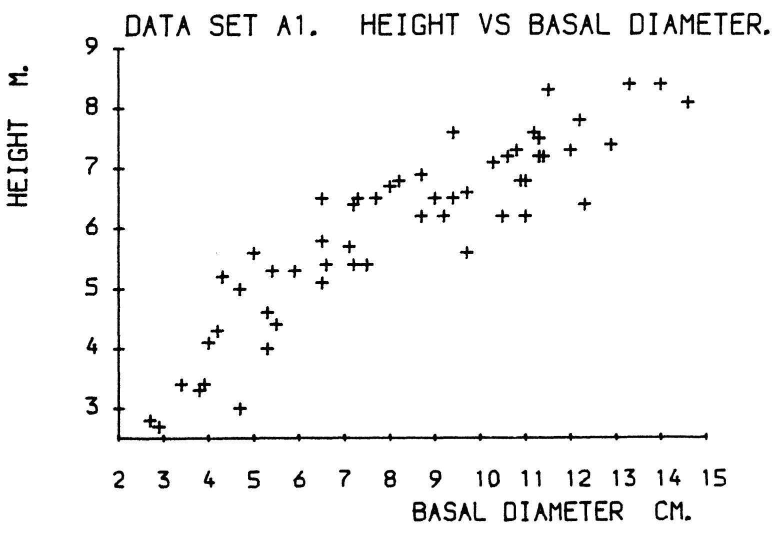
7.1 Biomass equations.

Single entry tables based on DBH or basal diameter, (BD, .10m) are given for young trees. Some of the A. auriculiformis seed sources commonly used in Nepal are branchy and do not develop a clear main stem until two or three years of age. These poor form seed lots have come from commercial seed suppliers in India, and no information about the origin of the seed collections was available. Tables based on diameter at ground level should be used for very young stands or for stands of poor form. Diameter at ground level is a slightly better predictor variable than DBH as judged by the r^2, F, residual mean square and the percent precision. However the difference is slight, and for ease of application the tables based on DBH are recommended for older trees which have a single main stem.

The biomass tables are developed using data from experiments 13/83 and 10/83 at the F.R.P trial site at Adabhar. Before planting the site was fully cultivated by ox ploughing. The following two CSIRO seedlots, CSIRO # S13191 Darwin, New Territories, Australia, and CSIRO # S13499 Croll creek, Queensland, Australia, were planted at a spacing of 2 x 2m (13/83) and 1.5 x 1.5m (10/83). Seedlings were maintained in a weed free condition by cultivation of 1m diameter pits, and by cutting down the Imperata grass between the pits. Experiment 10/83 was systematically thinned to remove 50% of the stems at age 1.5 years, thereby reducing the stocking from 4,444 stems/ha to 2,222 stems/ha. At age 2.5 years, 55 trees were sampled for component biomass by the techniques already described. This is called data set A1, a plot of height and diameter are given in Figure 12.

The equation selected is **Ln Weight = a + b Ln DBH** or, for branchy trees, **Ln Weight = a + b Ln BD**. Oven dry and green weight biomass tables are given in Appendix A, based on this data set.

Figure 12. A. auriculiformis total height versus basal diameter.



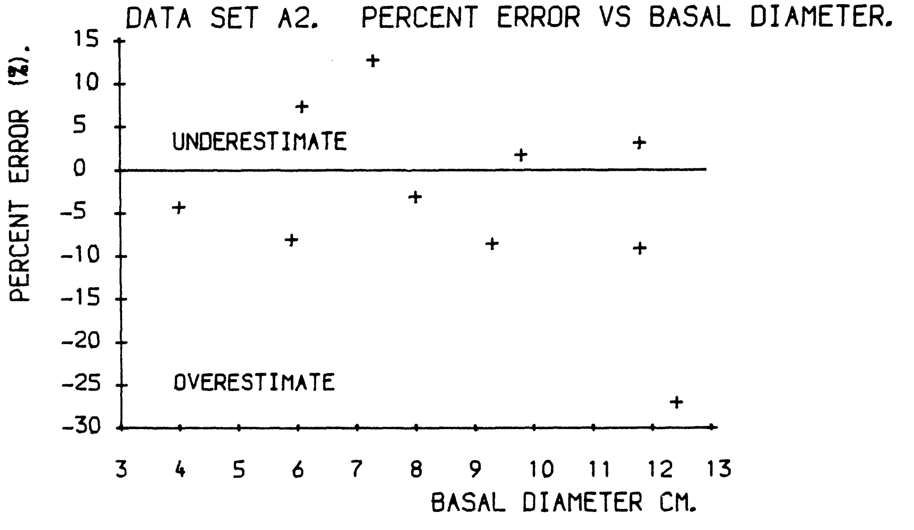
Validation of the A. auriculiformis biomass tables was carried out using two independent data sets. The first is from block 9C at Sagarnath, planted at a spacing of 2 x 4m and age 2.5 years. The seed was from an

Indian commercial supplier, but no information was available about the origin of the seed. The trees were of very poor form, with excessive branching, chlorotic leaves and slow growth. Seedlings were maintained by slash weeding around the trees for the first two years. Ten trees were sampled for the validation. This is referred to as data set A2.

The second validation sample is from the Adabhar trial site, and consists of 31 trees aged 1.5 to 2.5 years old. The spacing was 2 x 2m, and the trees were maintained in a weed free condition by cultivation of the soil for the first two years. This validation sample is data set A3.

Validation of the oven dry stem and branch equations, predicted from basal diameter, with data set A2 indicates that the equations are reasonably accurate. The predicted stem and branch weight is a 5.8% overestimate of the actual weights, with no obvious bias (see Figure 13). The regression of predicted versus actual weight indicates that the slope is equal to one and the intercept equal to zero. As the form of the trees in this validation sample are more variable than the trees which make up the regression data this is considered an acceptable prediction. The validation of the components of branch and leaf is comparable, but with much greater variability.

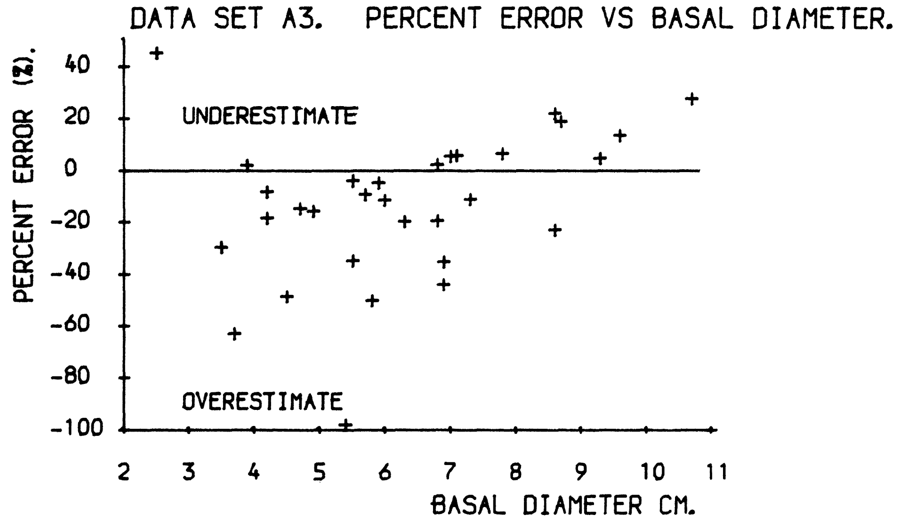
Figure 13. *A. auriculiformis* oven dry stem and branch validation.



The results for the oven dry stem and branch validation (regression based on BD) using data set A3 indicates some bias in the prediction. The predicted stem and branch weight is a 1.5% underestimate of the actual weight with a tendency to overestimate small trees and underestimate the larger diameter trees (see Figure 14). The regression of predicted versus actual weight shows that slope does not equal 1 nor does the intercept equal 0. Despite this, the bias is slight and the regression provides an adequate prediction for the purposes required. The equations based on DBH follow a similar pattern as the BD equations.

The *A. auriculiformis* biomass regressions are based on trees less than three years old. It will be essential to extend the validity of the tables to include larger trees as such trees become available. For the present, these equations are adequate for rough estimates of the early yield of fuelwood from short rotation plantations.

Figure 14. A. auriculiformis oven dry stem and branch validation.



Few other biomass equations are available for A. auriculiformis. Yantash, et al. (1985) gives green weight biomass equations, based on D^2H, for 1.3 and 2 year old trees. These equations have low r^2 values for most of the components, presumably because of the use of DBH as a predictor variable for trees too small to have developed a single main stem. MacDicken (1983) gives volume equations for one year old trees planted at a spacing of 1 x 1m. However these are of limited application as such small material is not merchantable in units of volume.

7.2 Wood density.

Oven dry wood density was measured by water displacement and oven drying for 2.5 year old trees from Adabhar. Stem sections with bark were taken from twelve trees growing at a spacing of 2 x 2m. The mean basic density was 468 kilos/m^3.

8.0 CASSIA SIAMEA.

8.1 Biomass equations.

C. siamea is a promising fuelwood species for use in community woodlots or village plantations where agroforestry or extensive weeding are not possible. When planted at a wide spacing, the tree develops a heavy spreading crown which shades out competing grasses and reduces the amount of weeding required for successful establishment. This characteristic limits its value for agroforestry plantations, except at very wide spacings, as it competes strongly with the agricultural crops for light and moisture. This is useful in situations where the weeding costs must be minimized and agricultural intercropping is not feasible. Most of the fuelwood is in the branches, which reduces its value for large scale industrial plantations because of the high cost of handling the branch material. However, in community forest situations the availability of labour is rarely a constraint and branches are widely accepted for firewood. Cattle and goats do not readily eat C. siamea leaves which is a great advantage in establishing the tree in areas with uncontrolled grazing. Although the leaves are unpalatable they are produced in large quantities and can be used for cattle bedding and compost production.

Unlike the biomass tables for the other species, those for C. siamea are considered preliminary, and should be used with caution. The regressions are based on an unbalanced data set, which consists only of very young trees. The effect of tree spacing on leaf biomass is unclear and the leaf component is excluded. The equations produced will be useful for making rough estimates of growth and yield, but should not be used outside the range of conditions described without further validation. These tables should be revised as soon as sufficient data is available in the field to include a wider range of tree sizes, to test the effect of spacing on biomass production and to evaluate other predictor variables.

Biomass regressions for the components of stem and branch (fuelwood) and total biomass are based on the equation **Ln Weight = a + b Ln BD** where basal diameter is measured at a height of 5 to 10cm. C. siamea does not develop a single main stem until age three or four years, and often produces many branches at a height of 20 to 40 cms. Basal diameter is therefore used as the predictor variable for young trees. The use of basal diameter as a predictor variable may be unreliable when trees have irregular swelling in the stem. This appears to be the case for older trees, but does not occur in the data tested until a diameter greater than 14 cm. For trees with a basal diameter greater than this, it will be necessary to develop new tables based on DBH.

The biomass equations are prepared from 78 trees collected from two sites at Sagarnath and two at Adabhar. The Sagarnath data, from block 11B and 9C, is 2.5 year old C. siamea planted at a spacing of 2 x 4 m. The Adabhar data is from experiments 10/83 and 14/83, planted at a spacing of 1.5 x 1.5 m and 2.1 x 2.1m respectively. Three month old seedlings were planted after full site cultivation, and were maintained in a weed free condition for the first year by agricultural intercropping. The biomass equations were prepared using the techniques given in section 3.

The plots of Ln stem and branch versus Ln BD (see Figure 15) show a nonlinear tendency for trees greater than 14 cm, possibly due to swelling of the stem. These trees were removed from the data before biomass regressions were calculated. For trees greater than 14cm in basal diameter DBH should be used as a predictor variable.

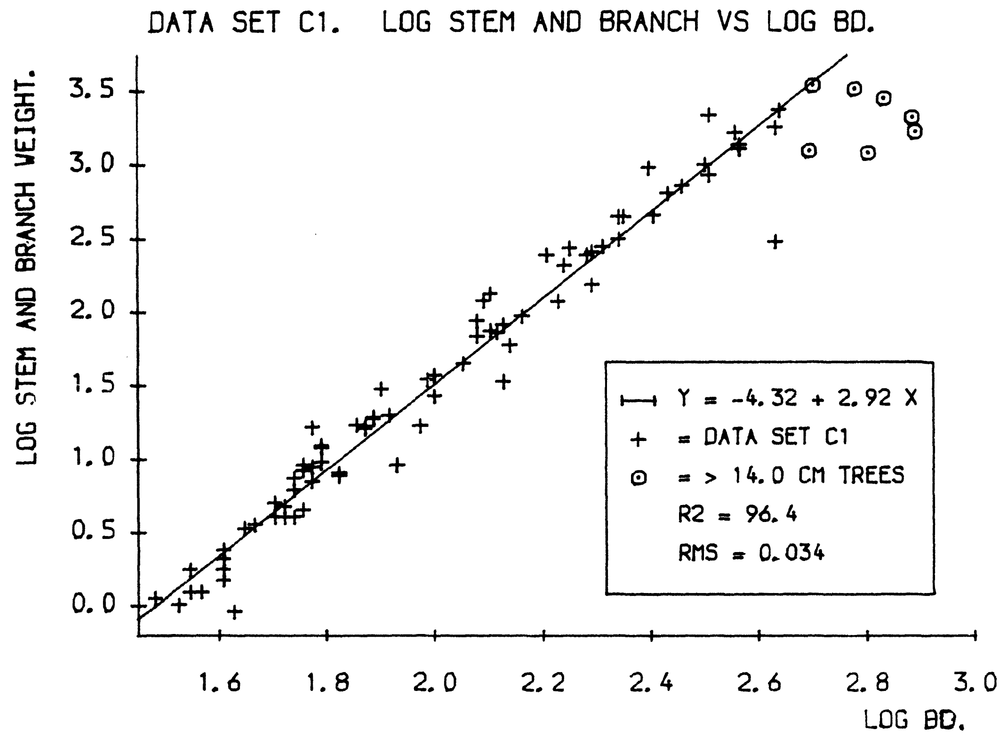
The need to include height as a predictor variable was tested by comparing the equation **Ln Stem and branch = a + b Ln BD** with the double entry equation **Ln Stem and branch = a + b Ln BD + Ln Height**. The addition of height improved the r^2 from 96.5 to 98.0. However, the residual analysis does not indicate a better fit and the single entry table is chosen because of the increased efficiency in the field. The equations calculated are given in Appendix A.

Validation of the biomass equations was carried out using a sample of 15 trees age 2.5 years old from Adabhar. This plot was originally planted at a spacing of 1.5 x 1.5m and then thinned to a spacing of 2.1 x 2.1m at age 1.5 years. Validation of the green weight tables indicates that the equations give a reasonable estimate, but that some bias is evident.

TABLE 4. C. siamea Validation Results

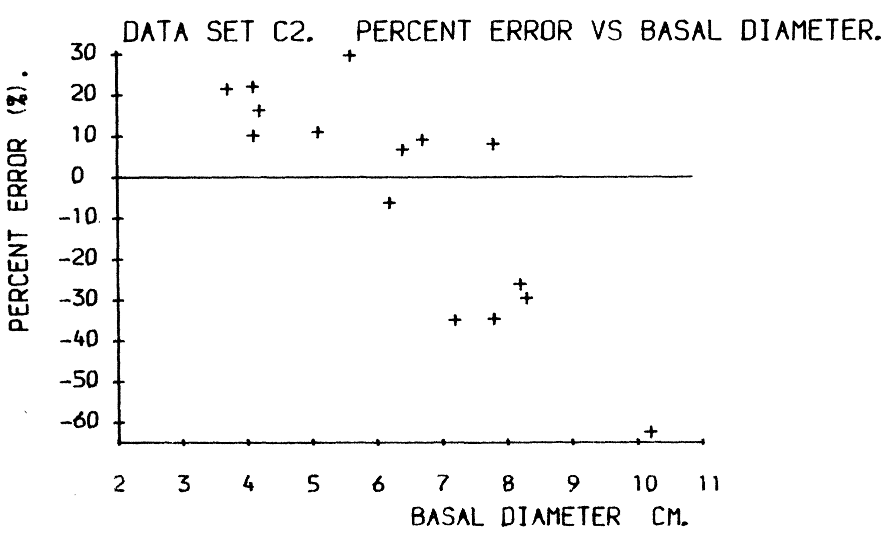
Component.	Plot Prediction Error	Student's **t** Test, 95%
Stem and branch	15 % overestimate	slope = 1, intercept = 0
Total	8 % overestimate	slope ≠ 1, intercept ≠ 0

Figure 15. C. siamea Ln oven dry stem and branch weight versus Ln BD, showing nonlinear tendency for trees greater than 14cm BD. These trees were removed from the data set before analysis.



The plot of percent error versus BD for the fuelwood component (stem and branch), shows an underestimate of the small diameter trees and an overestimate of the larger trees (see Figure 16). This is possibly an effect of the original close spacing of the validation sample which prevented the development of a wide crown. The C. siamea tables should be valid for trees from 4 to 14cm BD which are planted at a spacing of 2 x 2m or wider. A new validation sample should be calculated before using the tables for other spacings or sizes.

Figure 16. C. siamea green weight stem and branch validation



No other biomass tables were found for C. siamea during a literature search, except for green weight tables produced by Yantasath, et al. (1985). These are based on D^2H, and are from 1.3 and 2 year old trees at a stocking of 10,000 stems per ha. The equations have very low r^2 values, perhaps because of the use of DBH as a predictor variable. Estimates from these equations are not directly comparable due to the inclusion of height as a predictor variable.

8.2 Density.

Samples of stem wood with bark were taken from seven 2.5 year old trees from Adabhar. The mean oven dry wood density is 400 kilos per m^3.

9.0 UTILIZATION OF THE TABLES.

A simple inventory form for the use of the biomass or volume tables in the field is given in Appendix C, along with an actual worked example. The format is designed to allow quick and simple calculation of yield and it avoids the use of confidence limits and statistics. The people who will have to apply these tables are technical and ranger level H.M.G.N. staff with limited mathematical or statistical background. If a simple practical method of applying the tables is not available, then they are unlikely to be used.

Sample plots should be established on sites typical of the plantation area. The plot should be large enough to include a minimum of 100 trees. The actual plot size required will vary, depending on survival and the initial stocking. Some examples of plot area for various spacings are given on the inventory form. Alternatively, the plot may be considered as several rows of trees, for instance 4 rows of 25 trees, and each sample row separated by 5 rows. This system is faster and simpler to operate as it does not require measuring and establishing plot boundaries on the ground. On the sample plot the DBH (or BD) of every tree is measured by 1 cm classes, and the number of trees per each class is recorded. DBH should always be located by using a height stick to ensure accuracy. All dead, missing or seriously damaged trees should be counted as dead trees and recorded on the form. The predicted weight from the biomass (or volume) table for the component and species required is copied on to the inventory sheet. The number of stems in each diameter class is then multiplied by the weight in column B and recorded in column C. The predicted weights are then added together and divided by the total number of trees measured. This number is multiplied by the actual stocking/ha to give the weight (or volume) per ha.

10.0 YIELD ESTIMATES.

Fuelwood plantations are a new concept in the Bhabar-Terai and very few growth estimates are available. The biomass equations developed were used to estimate the fuelwood yield of each species on various sites and at different spacings. This was not part of a planned inventory, but uses data collected at various times as part of the silvicultural research either from operational plantations at Sagarnath or from F.R.P. trial plots. The data provides estimates for comparison between species, spacing and site. The results are presented in Table 4. Volume results are not given for the very short rotation material which is best handled on a weight basis.

These preliminary results clearly show that E. camaldulensis (Petford provenance) is the most productive fuelwood species, followed by C. siamea. The latter species has a poor yield at very close spacings as it requires more area per tree than any of the other species. There is little purpose in planting C. siamea on short rotation intensive plantations and it will probably produce the highest yields at an approximate stocking of 1,000 stems per ha. The yield of sissoo on a good site (block 3B) is half that of the eucalyptus on a similar site (block 5A) and the sissoo growth declines to very low levels on the drier sites (Laxminiya plot). Sissoo is a riverine species and does not naturally occur on extremely dry soils, it is therefore advisable to limit the planting of sissoo to those sites with an accessible water table. On the drier sites E. camaldulensis can produce a MAI at age 5 years of approximately 15-20 oven dry tons of fuelwood per ha when maintained in a weed free condition during the initial 3 years. The weed growth can be controlled at a low cost by the use of agricultural intercrops. The fuelwood yield of A. auriculiformis is low; this may have been due to insufficient weeding in the establishment phase, or the use of a poor seed source. Further plantings are required to test the full potential of this species. At the Chitripani inner Terai site the growth of A. auriculiformis has been reasonable despite an extremely poor site.

The very close spacing plots (10,000 stems per ha) have not produced substantially higher yields than the more standard 2 x 2m spacing although the total fuelwood yield at age 1.5 years is high, at approximately 15 tons per ha. A characteristic of the Bhabar sites is strong between tree competition, primarily for moisture. With an initial 1.5 year rotation followed by annual coppice crops the optimum stocking is approximately 4,000 stems per ha, or perhaps a 1.5 x 1.5m spacing. The large number of small size stems produced by this system are of limited utility for industrial fuelwood where handling costs are high. The management and harvesting of village or community woodlots has few labour constraints and the close spaced short rotation is the best method of maximizing growth, ensuring an early and frequent fuelwood harvest and maintaining community interest in the plantations.

Table 4.

ESTIMATED OVEN DRY FUELWOOD (Stem and Branch) AND OVERBARK VOLUME YIELD.

Location	Age. Years	Initial Stocking. Stems/ha	Survival Percent.	Total Fuelwood. Tons/ha	Fuelwood MAI. Tons/ha/yr	OB Volume MAI. M^3/ha/yr
EUCALYPTUS CAMALDULENSIS						
Sagarnath Spacing trial	2.3	1,250	90%	15.8	6.9	12.3
Sagarnath Block 5A	4.4	1,600	91%	63.4	14.4	25.4
Adabhar 28/84	1.5	10,000	98%	15.3	10.2	-
Adabhar 28/84	1.5	2,500	96%	14.9	9.9	-
DALBERGIA SISSOO						
Sagarnath (dry site) Laxmaniya Plot	9.5	2,500	83%	24.4	2.6	4.3
Sagarnath (good site) Block 3B	5.0	1,600	89%	36.6	7.3	11.8
Adabhar 28/84	1.5	10,000	98%	9.4	6.3	-
Adabhar 28/84	1.5	2,500	99%	5.2	3.5	-
ACACIA AURICULIFORMIS						
Sagarnath Block 9C.	2.5	1,250	87%	10.6	4.2	-
Chitripani Inner Terai	5.5	1,600	100%	41.1	7.5	-
CASSIA SIAMEA						
Sagarnath Block 11B	2.5	1,250	96%	26.1	10.4	-
Adabhar 28/84	1.5	10,000	100%	5.1	3.4	-
Adabhar 28/84	1.5	2,500	100%	8.1	5.4	-

1. Sagarnath data, all plots were planted into disced soil and maintained in a weed free condition for 18 months.

2. Laxmaniya plot was planted by the Forest Survey and Research Office into 1m diameter pits and pit weeded for the first four years.

3. All Adabhar plots were planted into fully cultivated soil and maintained in a weed free condition for 18 months. 28/84 is the F.R.P. trial number.

4. Estimates of yield are within 10 to 15 percent of the actual amount.

11.0 CONCLUSIONS

Intensive short rotation forestry in the Nepal Terai is in its infancy. The early plantations have demonstrated the high potential yield, the appropriate species and the silvicultural techniques required. Refinement of these techniques will ensure increased yields, while better integration of agricultural production with the tree crop will improve the social impact of the plantations. Biomass yield estimates are an important tool in the management of these forests, both for the large semi-industrial plantation and the small village woodlot. The biomass equations presented in this paper are an early attempt to provide yield estimates for these Terai plantations. The tables will need to be revised and improved in a few years time when more data and new establishment techniques are available. In the interim period these tables will provide adequate estimates of the yield of existing plantations.

It is important that biomass research carried out in Nepal is done in such a way that other foresters, both Nepali and expatriate, can have access to the original data to facilitate the revision of the equations. It is also essential that biomass research carried out in Nepal uses techniques which are consistent and comparable with other research workers. The proliferation of incompatible biomass research is of no long term value to forestry in Nepal. Applegate, et al. (1985) have recommended that a copy of the original data and the results of all biomass studies in Nepal be kept at the F.S.R.O. library in Kathmandu. The data for this study are available by request through the F.R.P. of the F.S.R.O. Details about the biomass tables, samples and their statistics are given in Appendix A, following a standard format devised by Ian Thompson for biomass research in the middle hills of Nepal. Appendix B contains frequency tables for the biomass and volume table samples.

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APPENDIX A.

SPECIES *Eucalyptus camaldulensis*

Diameter at DBH, 1.3m

Oven dry weight in kilos

OVEN DRY WEIGHT BIOMASS TABLE

DBH cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	(.28)	(.23)	(.18)	(.03)	(.04)
2	.99	.83	.67	.12	.12
3	2.28	1.95	1.60	.27	.25
4	4.24	3.68	3.04	.50	.44
5	6.95	6.11	5.09	.82	.68
6	10.49	9.33	7.81	1.24	.99
7	14.93	13.41	11.27	1.77	1.35
8	20.33	18.41	15.54	2.42	1.78
9	26.75	24.39	20.66	3.19	2.27
10	34.23	31.43	26.71	4.08	2.83
11	42.84	39.57	33.72	5.11	3.46
12	52.63	48.87	41.76	6.29	4.15
13	63.63	59.38	50.86	7.61	4.92
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Numbers in brackets are outside the biomass sample DBH size.

Sample

Location(s)	Sagarnath and Adabhar, 9 plots.		
Forest type	Plantation	Age(s)	0.7 to 3.5 years.
Management	1 x 1m, 1.4 x 1.4m, 2.5 x 2.5m and 4 x 1.7m spacing.		
Site disced and seedlings planted into fully cultivated soil.			
Clean weeded for the first two years by agricultural intercropping			
Diameter range	2.0 to 13.6 cm	Height range	2.8 to 18.1m
Number of trees	88 trees.		

Regression
Model: Ln Weight = a + b Ln DBH

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-2.2660	-2.5055	-2.7421	-4.4173	-4.1242
Slope b	2.4663	2.5318	2.5632	2.4768	2.1966
Residual mean square	0.036	0.038	0.016	0.041	0.272
Adjusted r2 (%)	99.7	98.1	99.1	79.0	81.9
F (from ANOVA)	3,3368.0	4,732.0	9,094.0	331.0	394.0
Percent Precision (%)	8.3	7.8	5.5	28.3	23.0

The table values are based on the midpoint of each 1 cm DBH class.
For example, the 4 cm class includes all trees from 4.00 to 4.99 cm.

SPECIES **Eucalyptus camaldulensis**

Diameter at DBH, 1.3m

Green weight in kilos

GREEN WEIGHT BIOMASS TABLE

DBH cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	(.72)	(.57)	(.48)	(.06)	(.10)
2	2.47	2.04	1.73	.23	.30
3	5.58	4.72	4.03	.52	.64
4	10.25	8.82	7.58	.95	1.11
5	16.67	14.53	12.56	1.56	1.74
6	24.99	22.02	19.11	2.35	2.51
7	35.34	31.44	27.38	3.33	3.45
8	47.86	42.93	37.50	4.53	4.56
9	62.66	56.62	49.60	5.94	5.83
10	79.85	72.63	63.78	7.59	7.28
11	99.55	91.09	80.16	9.49	8.90
12	121.83	112.09	98.85	11.63	10.71
13	146.80	135.76	119.94	14.05	12.70
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Numbers in brackets are outside the biomass sample DBH size.

Sample

Location(s)	Sagarnath and Adabhar, 9 plots.		
Forest type	Plantation	Age(s)	0.7 to 3.5 years.
Management	1 x 1m, 1.4 x 1.4m, 2.5 x 2.5m and 4 x 1.7m spacing.		
Site disced and seedlings planted into fully cultivated soil.			
Clean weeded for the first two years by agricultural intercropping.			
Diameter range	2.0 to 13.6 cm	Height range	2.8 to 18.1m
Number of trees	88 trees.		

Regression
Model: Ln Weight = a + b Ln DBH

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-1.3167	-1.5667	-1.7536	-3.7296	-3.2265
Slope b	2.4228	2.4888	2.5130	2.4482	2.2163
Residual mean square	0.028	0.025	0.015	0.041	0.274
Adjusted r2 (%)	98.2	98.4	99.1	78.8	82.0
F (from ANOVA)	4,334.0	4,573.0	9,179.0	324.0	398.0
Percent Precision (%)	7.4	7.0	5.4	28.2	22.9

SPECIES **Eucalyptus camaldulensis**

Diameter at DBH, 1.3m

Stem volume in cubic metres
to a 2 cm top diameter.

VOLUME TABLE

DBH cm	OVERBARK VOLUME	UNDERBARK VOLUME
1	.0004	.0003
2	.0016	.0011
3	.0036	.0026
4	.0068	.0050
5	.0112	.0083
6	.0169	.0128
7	.0242	.0185
8	.0330	.0256
9	.0436	.0341
10	.0559	.0441
11	.0700	.0557
12	.0862	.0690
13	.1044	.0841
14	.1247	.1010
15	.1472	.1200
16	.1719	.1409
17	.1990	.1639
18	-	-
19	-	-
20		-

Sample

Location(s)	Sagarnath, 4 blocks.		
Forest type	Plantation.	Age(s)	1.5 to 4.5 years.
Management	2 x 4m and 2.5 x 2.5m spacing. Planted into fully cultivated soil. Clean weeded for the first two years by agricultural intercropping.		
Diameter range	1.5 to 17.2 cm	Height range	2.2 to 19.8 m
Number of trees	163 trees.		

Regression
Model: Ln Volume = a + b Ln DBH

Log correction factor not used.

Dependent Variables	OVERBARK VOLUME	UNDERBARK VOLUME
Intercept a	-8.7329	-9.1708
Slope b	2.4871	2.5723
Residual mean square	0.026	0.027
Adjusted r2 (%)	99.1	99.1
F (from ANOVA)	7,059.0	7,342.0
Percent precision (%)	5.2	5.5

SPECIES **Dalbergia sissoo**

Diameter at DBH, 1.3m.

Oven dry weight in kilos

OVEN DRY WEIGHT BIOMASS TABLE

DBH cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	-	(.20)	(.15)	(.06)	-
2	-	(.73)	(.55)	(.18)	-
3	-	(1.69)	(1.31)	(.38)	-
4	-	3.16	2.49	.66	-
5	-	5.22	4.17	1.04	-
6	-	7.92	6.39	1.50	-
7	-	11.33	9.21	2.06	-
8	-	15.50	12.69	2.72	-
9	-	20.47	16.87	3.48	-
10	-	26.29	21.79	4.34	-
11	-	33.00	27.51	5.30	-
12	-	40.65	34.05	6.38	-
13	-	49.28	41.46	7.57	-
14	-	58.92	49.78	8.86	-
15	-	69.61	59.05	10.27	-
16	-	81.39	69.29	11.80	-
17	-	94.30	80.55	13.44	-
18	-	108.35	92.86	15.20	-
19	-	123.60	106.25	17.08	-
20	-	140.06	120.76	19.08	-
21	-	157.77	136.41	21.20	

Numbers in brackets are outside the biomass sample DBH size.

Sample

Location(s)	Sagarnath. Blocks 5A, 6, 2A and 3A.
Forest type	Plantation. Age(s) 2 to 11 years.
Management	2 x 2 and 2 x 4m spacing. Weeded for the first two years by pit weeding, some of the plots cleaned by agricultural intercropping. No fertiliser used.
Diameter range	4.5 to 21.1 cm Height range 4.7 to 15.9 m
Number of trees	42 trees.

Regression
Model: Ln Weight = a + b Ln DBH

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-	-2.6105	-2.9355	-3.7385	-
Slope b	-	2.5005	2.5590	2.2139	-
Residual mean square	-	0.011	0.014	0.054	-
Adjusted r2 (%)	-	99.0	98.7	93.9	-
F (from ANOVA)	-	4,000.0	3,291.0	639.0	-
Percent Precision (%)	-	6.5	7.5	14.7	-

SPECIES **Dalbergia sissoo**

Diameter at DBH, 1.3m.

Green weight in kilos

GREEN WEIGHT BIOMASS TABLE

DBH cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	-	(.44)	(.33)	(.13)	-
2	-	(1.58)	(1.20)	(.39)	-
3	-	(3.66)	(2.85)	(.83)	-
4	-	6.87	5.42	1.44	-
5	-	11.34	9.06	2.25	-
6	-	17.23	13.89	3.26	-
7	-	24.64	20.03	4.48	-
8	-	33.69	27.59	5.91	-
9	-	44.49	36.67	7.56	-
10	-	57.15	47.38	9.43	-
11	-	71.74	59.80	11.53	-
12	-	88.37	74.02	13.87	-
13	-	107.13	90.13	16.45	-
14	-	128.09	108.22	19.27	-
15	-	151.33	128.36	22.33	-
16	-	176.94	150.63	25.65	-
17	-	204.98	175.10	29.22	-
18	-	235.54	201.86	33.04	-
19	-	268.68	230.97	37.13	-
20	-	304.47	262.50	41.47	-
21	-	342.47	296.53	46.08	

Numbers in brackets are outside the biomass sample DBH size.

Sample

Location(s)	Sagarnath. Blocks 5A, 6, 2A and 3A.		
Forest type	Plantation.	Age(s)	2 to 11 years.
Management	2 x 2 and 2 x 4m spacing. Weeded for the first two years by pit weeding, some of the plots cleaned by agricultural intercropping. No fertiliser used.		
Diameter range	4.5 to 21.1 cm	Height range	4.7 to 15.9 m
Number of trees	42 trees.		

Regression
Model: Ln Weight = a + b Ln DBH

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-	-1.8340	-2.1590	-2.9619	-
Slope b	-	2.5005	2.5590	2.2139	-
Residual mean square	-	0.011	0.014	0.054	-
Adjusted r2 (%)	-	99.0	98.7	93.9	-
F (from ANOVA)	-	4,000.0	3,291.0	639.0	-
Percent Precision (%)	-	6.5	7.5	14.6	-

SPECIES **Dalbergia sissoo**

Diameter at DBH, 1.3m

Stem volume in cubic metres
to a 2 cm top diameter.

VOLUME TABLE

DBH cm	OVERBARK VOLUME	UNDERBARK VOLUME
1	(.0004)	(.0003)
2	(.0014)	(.0010)
3	(.0031)	(.0023)
4	.0056	.0042
5	.0091	.0068
6	.0136	.0102
7	.0191	.0144
8	.0258	.0194
9	.0337	.0253
10	.0429	.0322
11	.0534	.0400
12	.0652	.0488
13	.0784	.0587
14	.0931	.0697
15	.1092	.0817
16	.1269	.0949
17	.1462	.1093
18	.1670	.1249
19	.1895	.1417
20	.2137	.1597
21	.2396	.1790

Numbers in brackets are outside the volume sample DBH size.

Sample

Location(s)	Sagarnath. Blocks 5A, 6, 2A and 3A.		
Forest type	Plantation.	Age(s)	2 to 11 years.
Management	2 x 2m and 2 x 4m spacing. Weeded for the first two years by pit weeding, some of the plots cleaned by agricultural intercropping. No fertiliser used.		
Diameter range	4.5 to 21.1 cm	Height range	4.7 to 15.9 m
Number of trees	42 trees.		

Regression
Model: Ln Volume = a + b Ln DBH

Log correction factor not used.

Dependent Variables	OVERBARK VOLUME	UNDERBARK VOLUME
Intercept a	-8.7927	-9.0705
Slope b	2.4002	2.3957
Residual mean square	0.012	0.014
Adjusted r2 (%)	98.8	98.6
F (from ANOVA)	3,378.0	2,885.0
Percent precision (%)	7.1	7.5

SPECIES **Acacia auriculiformis**

Diameter at DBH, 1.3 m.

Oven dry weight in Kilos.

OVEN DRY WEIGHT BIOMASS TABLE

DBH cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	.56	.39	.30	.08	.17
2	1.75	1.26	.96	.28	.48
3	3.71	2.73	2.07	.62	.95
4	6.51	4.87	3.68	1.14	1.58
5	10.20	7.73	5.83	1.85	2.37
6	14.82	11.37	8.53	2.76	3.33
7	20.41	15.81	11.83	3.90	4.46
8	27.00	21.09	15.75	5.28	5.75
9	34.62	27.25	20.31	6.90	7.21
10	43.30	34.32	25.53	8.79	8.83
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Sample

Location(s)	Adabhar. Experiments 13/83 and 10/83		
Forest type	Plantation	Age(s)	3 years
Management	2 x 2m and 1.5 x 1.5m spacing. Pit weeded for the first two years by digging 1m diameter pits. Weeding by grass cutting in the third year. No fertiliser used.		
Diameter range	1.7 to 10.1 cm.	Height range	2.7 to 8.4 m
Number of trees	55 trees.		

Regression
Model: Ln Weight = a + b Ln DBH

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-1.4886	-1.8825	-2.1333	-3.5013	-2.6002
Slope b	2.2356	2.3043	2.2851	2.4133	2.0323
Residual mean square	0.070	0.072	0.062	0.188	0.143
Adjusted r2 (%)	94.1	94.2	94.9	87.3	86.5
F (from ANOVA)	858.0	881.0	1,013.0	371.0	346.0
Percent Precision (%)	14.7	14.9	13.7	24.1	21.1

SPECIES **Acacia auriculiformis**

Diameter at DBH, 1.3 m.

Green weight in Kilos.

GREEN WEIGHT BIOMASS TABLE

DBH cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	1.02	.74	.58	.15	.28
2	3.22	2.42	1.85	.52	.78
3	6.85	5.24	4.00	1.17	1.54
4	12.04	9.36	7.11	2.15	2.57
5	18.89	14.86	11.24	3.49	3.87
6	27.47	21.83	16.47	5.23	5.44
7	37.87	30.36	22.83	7.39	7.27
8	50.15	40.50	30.39	9.99	9.37
9	64.36	52.33	39.19	13.06	11.75
10	80.56	65.91	49.26	16.63	14.40
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Sample

Location(s)	Adabhar. Experiments 13/83 and 10/83		
Forest type	Plantation	Age(s)	3 years
Management	2 x 2m and 1.5 x 1.5m spacing. Pit weeded for the first two years by digging 1m diameter pits. Weeding by grass cutting in the third year. No fertiliser used.		
Diameter range	1.7 to 10.1 cm.	Height range	2.7 to 8.4 m
Number of trees	55 trees.		

Regression

Model: Ln Weight = a + b Ln DBH

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-.8859	-1.2292	-1.4759	-2.8628	[redacted]
Slope b	2.2433	2.3039	2.2851	2.4133	[redacted]
Residual mean square	0.069	0.072	0.062	0.188	0.143
Adjusted r2 (%)	94.1	94.2	94.9	87.3	86.5
F (from ANOVA)	868.0	883.0	1,013.0	371.0	345.0
Percent Precision (%)	14.7	14.9	13.8	24.1	20.9

SPECIES **Acacia auriculiformis**

BD, basal diameter.

Oven dry weight in Kilos.

OVEN DRY WEIGHT BIOMASS TABLE

BD cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	-	-	-	-	-
2	.49	.34	.27	.07	.15
3	1.14	.81	.63	.17	.32
4	2.13	1.54	1.19	.34	.57
5	3.52	2.59	1.98	.58	.90
6	5.35	3.98	3.02	.92	1.32
7	7.66	5.75	4.34	1.35	1.83
8	10.47	7.94	5.97	1.90	2.43
9	13.83	10.57	7.92	2.58	3.14
10	17.77	13.68	10.22	3.39	3.94
11	22.31	17.29	12.87	4.35	4.85
12	27.48	21.44	15.91	5.46	5.87
13	33.32	26.13	19.35	6.74	7.00
14	39.84	31.41	23.20	8.19	8.24
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Sample

Location(s)	Adabhar. Experiments 13/83 and 10/83		
Forest type	Plantation	Age(s)	3 years
Management	2 x 2m and 1.5 x 1.5m spacing. Pit weeded for the first two years by digging 1m diameter pits. Weeding by grass cutting in the third year. No fertiliser used.		
Diameter range	2.7 to 14.6 cm.	Height range	2.7 to 8.4 m
Number of trees	55 trees.		

Regression
Model: Ln Weight = a + b Ln BD

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-3.0061	-3.4383	-3.6519	-5.2007	-3.9977
Slope b	2.5021	2.5748	2.5415	2.7312	2.2835
Residual mean square	0.022	0.026	0.028	0.102	0.096
Adjusted r2 (%)	98.1	97.9	97.7	93.1	90.9
F (from ANOVA)	2,776.0	2,548.0	2,323.0	730.0	541.0
Percent Precision (%)	8.4	9.1	9.2	17.9	17.3

SPECIES ***Cassia siamea***

BD, basal diameter.

Oven dry weight in kilos

OVEN DRY WEIGHT BIOMASS TABLE

BD cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	-	-	-	-	-
2	(.33)	(.19)	-	-	-
3	(.79)	(.52)	-	-	-
4	1.54	1.08	-	-	-
5	2.61	1.93	-	-	-
6	4.06	3.15	-	-	-
7	5.92	4.78	-	-	-
8	8.24	6.88	-	-	-
9	11.04	9.52	-	-	-
10	14.37	12.75	-	-	-
11	18.27	16.63	-	-	-
12	22.76	21.22	-	-	-
13	27.88	26.56	-	-	-
14	33.66	32.72	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Numbers in brackets are outside the biomass sample BD size.

Sample

Location(s)	Adabhar, Expt. 10/83, 14/83. Sagarnath block 11B, 9C		
Forest type	Plantation.	Age(s)	1.5, 2.5, 2.5 and 2.6 yrs
Management	1.5 x 1.5m, 2.1 x 2.1m and 2 x 4m spacing. Soil clean cultivated before planting. Weeding maintained for first 1.5 years by soil cultivation. No fertiliser used.		
Diameter range	4.4 to 14 cm	Height range	2.8 to 7.8 m
Number of trees	78 trees.		

Regression
Model: Ln Weight = a + b Ln BD

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-3.5323	-4.3165	-	-	-
Slope b	2.6358	2.9185	-	-	-
Residual mean square	0.035	0.034	-	-	-
Adjusted r2 (%)	95.5	96.4	-	-	-
F (from ANOVA)	1,632.0	2,079.0	-	-	-
Percent Precision (%)	8.4	8.4	-	-	-

SPECIES **Cassia siamea**

BD, basal diameter.

Green weight in kilos

GREEN WEIGHT BIOMASS TABLE

BD cm	Total weight	Stem & branch	Stem	Branch	Leaf
1	-	-	-	-	-
2	(.72)	(.43)	-	-	-
3	(1.73)	(1.14)	-	-	-
4	3.35	2.35	-	-	-
5	5.66	4.21	-	-	-
6	8.77	6.82	-	-	-
7	12.77	10.33	-	-	-
8	17.73	14.85	-	-	-
9	23.73	20.50	-	-	-
10	30.84	27.39	-	-	-
11	39.15	36.65	-	-	-
12	48.71	45.40	-	-	-
13	59.60	56.74	-	-	-
14	71.88	69.80	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

Numbers in brackets are outside the biomass sample BD size.

Sample

Location(s)	Adabhar, Expt. 10/83, 14/83. Sagarnath block 11B, 9C		
Forest type	Plantation.	Age(s)	1.5, 2.5, 2.5 and 2.6 yrs
Management	1.5 x 1.5m, 2.1 x 2.1m and 2 x 4m spacing. Soil clean cultivated before planting. Weeding maintained for first 1.5 years by soil cultivation. No fertiliser used.		
Diameter range	4.4 to 14 cm	Height range	2.8 to 7.8 m
Number of trees	78 trees.		

Regression
Model: Ln Weight = a + b Ln BD

Log correction factor not used.

Dependent Variables	Total	Stem & Branch	Stem	Branch	Leaf
Intercept a	-2.7348	-3.5036	-	-	-
Slope b	2.6213	2.8978	-	-	-
Residual mean square	0.035	0.033	-	-	-
Adjusted r2 (%)	95.5	96.4	-	-	-
F (from ANOVA)	1,614.0	2,092.0	-	-	-
Percent Precision (%)	8.5	8.3	-	-	-

APPENDIX B. Frequency Table for *Eucalyptus camaldulensis* Biomass.

DBH in cm.	Height in metres. 2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	Total
2.0	3	2	2	1	-	-	-	-	-	8
3.0	-	-	5	3	-	-	-	-	-	8
4.0	-	-	3	6	1	-	-	-	-	10
5.0	-	-	-	2	4	-	-	-	-	6
6.0	-	-	-	-	6	1	-	-	-	7
7.0	-	-	-	1	2	4	-	-	-	7
8.0	-	-	-	-	2	5	2	-	-	9
9.0	-	-	-	-	1	7	4	2	-	14
10.0	-	-	-	-	-	1	4	2	-	7
11.0	-	-	-	-	-	-	3	2	-	5
12.0	-	-	-	-	-	-	-	1	2	3
13.0	-	-	-	-	-	-	1	1	2	4
Total	3	2	10	13	16	18	14	8	4	88

Frequency Table for *Eucalyptus camaldulensis* Volume.

DBH in cm.	Height in metres. 2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	Total
1.0	7	4	-	-	-	-	-	-	-	-	11
2.0	-	10	1	-	-	-	-	-	-	-	11
3.0	-	8	2	-	-	-	-	-	-	-	10
4.0	-	1	8	2	-	-	-	-	-	-	11
5.0	-	-	2	8	1	-	-	-	-	-	11
6.0	-	-	-	5	6	-	-	-	-	-	11
7.0	-	-	-	5	5	1	-	-	-	-	11
8.0	-	-	-	2	2	4	3	-	-	-	11
9.0	-	-	-	-	-	4	6	-	-	-	10
10.0	-	-	-	-	-	1	9	-	-	-	10
11.0	-	-	-	-	-	-	9	-	1	-	10
12.0	-	-	-	-	-	-	1	5	4	-	10
13.0	-	-	-	-	-	-	-	4	6	-	10
14.0	-	-	-	-	-	-	1	3	6	-	10
15.0	-	-	-	-	-	-	-	4	6	-	10
16.0	-	-	-	-	-	-	-	4	1	-	5
17.0	-	-	-	-	-	-	-	-	-	1	1
Total	7	23	13	22	14	10	29	20	24	1	163

Frequency Table for *Cassia siamea* Biomass Sampling.

DBH in cm	Height in metres 2.0	3.0	4.0	5.0	6.0	7.0	Total
4.0	1	4	-	-	-	-	5
5.0	1	12	6	1	-	-	20
6.0	-	5	7	1	-	-	13
7.0	-	1	3	1	-	-	5
8.0	-	-	6	3	-	1	10
9.0	-	-	3	1	3	-	7
10.0	-	-	-	-	4	-	4
11.0	-	-	-	2	1	1	4
12.0	-	-	-	-	2	2	4
13.0	-	-	-	1	2	2	5
14.0	-	-	-	-	1	-	1
Total	2	22	25	10	13	6	78

Frequency Table for Dalbergia sissoo Biomass and Volume Sampling.

DBH in cm	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	Total
4.0	1	1	-	-	-	-	-	-	-	-	-	-	2
5.0	-	-	1	1	-	-	-	-	-	-	-	-	2
6.0	-	-	1	1	1	-	-	-	-	-	-	-	3
7.0	-	-	1	-	1	-	-	-	-	-	-	-	2
8.0	-	-	-	2	2	-	1	-	-	-	-	-	5
9.0	-	-	-	-	-	2	2	-	-	-	-	-	4
10.0	-	-	-	-	2	-	1	-	-	-	-	-	3
11.0	-	-	-	-	-	1	-	-	-	-	-	-	1
12.0	-	-	-	-	-	-	3	-	1	1	-	-	5
13.0	-	-	-	-	-	-	-	-	1	-	-	-	1
14.0	-	-	-	-	-	-	-	-	2	1	-	-	3
15.0	-	-	-	-	-	-	-	1	-	2	1	-	4
16.0	-	-	-	-	-	-	-	-	1	-	1	-	2
17.0	-	-	-	-	-	-	-	-	-	-	-	-	0
18.0	-	-	-	-	-	-	-	-	-	1	-	1	2
19.0	-	-	-	-	-	-	-	-	-	1	-	1	2
20.0	-	-	-	-	-	-	-	-	-	-	-	-	0
21.0	-	-	-	-	-	-	-	-	-	-	-	1	1
Total	1	1	3	4	6	3	7	1	5	6	2	3	42

Frequency Table for Acacia auriculiformis Biomass.
Based on DBH.

DBH in	Height in metres.							
cm.	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Total
1.0	2	1	-	-	-	-	-	3
2.0	-	3	2	-	-	-	-	5
3.0	-	-	2	3	1	-	-	6
4.0	-	-	1	7	1	-	-	9
5.0	-	-	-	2	5	1	-	8
6.0	-	-	-	-	8	3	-	11
7.0	-	-	-	-	2	5	-	7
8.0	-	-	-	-	-	2	1	3
9.0	-	-	-	-	-	-	2	2
10.0	-	-	-	-	-	-	1	1
Total	2	4	5	12	17	11	4	55

Frequency Table for Acacia auriculiformis Biomass.
Based on Basal diameter (BD)

BD in	Height in metres.							
cm.	2.0	3.0	4.0	5.0	6.0	7.0	8.0	Total
2.0	2	-	-	-	-	-	-	2
3.0	-	3	-	-	-	-	-	3
4.0	-	1	2	2	-	-	-	5
5.0	-	-	3	3	-	-	-	6
6.0	-	-	-	3	1	-	-	4
7.0	-	-	-	3	3	-	-	6
8.0	-	-	-	-	4	-	-	4
9.0	-	-	-	1	4	1	-	6
10.0	-	-	-	-	2	3	-	5
11.0	-	-	-	-	2	4	1	7
12.0	-	-	-	-	1	3	-	4
13.0	-	-	-	-	-	-	1	1
14.0	-	-	-	-	-	-	2	2
Total	2	4	5	12	17	11	4	55

APPENDIX C. INVENTORY SHEET. Fuelwood (oven dry stem and branch)

Location Sagarnath Block 2A

Species Dalbergia sissoo Measuring Date 23-4-1985

Planting Date September 1980 Age 4.7 years.

Spacing 2.5 x 2.5 m

DBH class	Tally Sheet	A Number of Trees	x B Value from table	= C (C)
1	I	1	.20	.20
2	I	1	.73	.73
3		0	1.69	–
4	II	2	3.16	6.32
5	IIII	4	5.22	20.88
6	IIII	4	7.92	31.68
7	I	1	11.33	11.33
8	I	1	15.50	15.50
9	~~IIII~~ IIII	9	20.47	184.23
10	IIII	4	26.29	105.16
11	II	2	33.00	66.00
12	~~IIII~~ II	7	40.65	284.55
13	IIII	4	49.28	197.12
14	II	2	58.92	117.84
15				
16				
17				
18				
19				
20				

Number of Dead Trees
~~IIII~~
~~IIII~~
I

Total Dead= 11 (D)

Number of Trees (E)= 42 | Total of C= 1,041.54 /E= 24.80 (J)

Total Number of Trees (F) = E + D = 53

Survival Percent (G)= E/F = .79 Initial stocking (H) = 1,600 S/ha

Actual Stocking (I) = G x H = 1,264 stems per ha.

Total Yield = I x J = 31,345 kilos per ha. /1,000 = 31.3 Tons per ha.

Spacing	Number of Stems/ha.	Square Sample Plot Size.	Area.
1.0 x 1.0m	10,000	10 x 10m	.01 ha
1.5 x 1.5m	4,444	15 x 15m	.02 ha
2.0 x 2.0m	2,500	20 x 20m	.04 ha
2.5 x 2.5m	1,600	25 x 25m	.06 ha
2.0 x 4.0m	1,250	30 x 30m	.09 ha
2.0 x 5.0m	1,000	32 x 32m	.10 ha

APPENDIX C. INVENTORY SHEET.

Location _

Species _ _ _ _ _ _ _ _ _ _ _ _ _ _ Measuring Date _ _ _ _ _ _ _

Planting Date _ _ _ _ _ _ Age _ _ _ _ _ _ years.

Spacing _ _ _ _ _ _ _ _ _

DBH class	Tally Sheet	A Number of Trees	x B Value from table	= C (C)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Number of Dead Trees

Total Dead= _ _ _ _ (D)

Number of Trees (E)= _ _ _ _ Total of C= _ _ _ _ _ /E= _ _ _ _ _ (J)

Total Number of Trees (F) = E + D = _ _ _ _ _ _ _

Survival Percent (G)= E/F = _ _ _ _ _ Initial stocking (H) = _ _ _ _ _ _S/ha

Actual Stocking (I) = G x H = _ _ _ _ _ _ stems per ha.

Total Yield = I x J = _ _ _ _ _ _ _ _per ha. /1,000 = _ _ _ _ _ _ per ha.

Spacing	Number of Stems/ha.	Square Sample Plot Size.	Area.
1.0 x 1.0m	10,000	10 x 10m	.01 ha
1.5 x 1.5m	4,444	15 x 15m	.02 ha
2.0 x 2.0m	2,500	20 x 20m	.04 ha
2.5 x 2.5m	1,600	25 x 25m	.06 ha
2.0 x 4.0m	1,250	30 x 30m	.09 ha
2.0 x 5.0m	1,000	32 x 32m	.10 ha