MODELLING FOR DETERMINATION OF BIOMASS OF *ACACIA NILOTICA, ACACIA ALBIDA, ACACIA TORTILIS* AND *PROSOPIS CINERARIA* IN ARID AREAS

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Abstract

Energy crisis demands determination of total biomass for estimation of fuelwood from trees of different sizes. Biomass in green form of four species grown in arid conditions was determined using five growth models. Out of these, allometric model gave better results which was used for estimation of stem, branch and total weight separately of trees with varying diameter at breast height.

Introduction

The term biomass has been defined differently by different authors. Commonly it is understood to be the living matter in plants, animal and human beings. Recent definitons are more specific to plants. Here again there is a difference of opinion. According to one definition biomass "is the amount of living matter in the form of one or more kinds of organisms (trees, shrubs, etc.) present in a particular habitat" (1). Further, tree biomass is the biomass of a tree and is defined as the woody plant having a main stem which when growing under normal conditions reaches a mature height of at least 7 m. This includes foliage, branches, stump and roots. Foliage comprises of leaves and needles, whereas branches are exlcusive of foliage. Another definiton states that vegetation or non-woody plants which are less than 31 cm in height are not considered as forest biomass (2). With energy crisis biomass has not only achieved high importance but has also been defined to include wood, agriculture residues, cattle dung and grasses.

In forestry operations uptill now volume tables were generally prepared to determine wood cubical contents of a tree main stem in relation to its dimater at breast height (dbh). The latter is an important tree variable due to ease of its measurement and strong relationship with stem volume. Total height is also related to the volume of a tree but its measurement is difficult. Therefore, dbh is generally used as a predictor for estimation of tree trunk volume.

Earlier, only wood volume was considered commercially important because of the use of tree stem for certain products like fuelwood, timber, poles and manufacture of plywood, pulp and paper from it. The above products are closely related to volume of the tree stem. However, during the last decade due to realization of importance of biomass as fuel and its scarcity, it has become necessary to know full biomass contents of the tree. Even small sized trees and their components, considered non-commercial previously have

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become commercially valuable. The foresters are, therefore, more interested in the 'complete tree concept' for biological, technological and practical reasons. Consequently, wood volume is being replaced by biomass determination to assess the useful contents of a tree. Furthermore, though, volume of the main stem can be assessed accurately, the volume estimation of numerous branches, twigs and leaves of a tree is almost impossible. As such determination of biomass by weight is considered to be a practical measure for those components. Assessment by weight is also necessary when small chips, particles or ground wood is used for making composite boards or other products as well as for their use as fuel. All this indicates the importance of determining biomass of a tree. This study aims at determination of productivity of four *Acacia* and *Prosopis* species in the form of biomass under arid conditions.

Material and Methods

Material

The present study was conducted in Dagar Kotli, Bhakkar district (Latitude 31°33′ N and Longitude 71°07′ E). The area is a part of Thal desert which receives an annual rainfall of about 200-300 mm only. Maximum summer temperature is generally as high as 48° C. The soils are moderately calcareous with brown fine sand and small canker formed of Indus alluvium. In this locality, a species trial was started in 1984 with the assistance of International Board for the Preservation of Plant Genetic Resource (IBPGR) of FAO who provided seedlots of *Acacia nilotica, Acacia albida, Acacia tortilis* and *Prosopis cineraria* for testing. Planting of one year seedlings was done on slopy catchments of 1 m width. Planting was done in pits of 0.5 m diameter and 0.3 m depth. After planting, hand watering of plants was carried out for one year at the rate of 4 litres/week in summer; the frequency was reduced to half in winter. The planting was done in randomised complete block design with 4 replications. Each plot contained 36 plants of each seedlot planted in a group of 6 × 6 plants at a spacing of 3 × 3 m in 4 replications.

Methods

The biomass of the trees of different seedlots of various species was measured in 1988. For this purpose, 33 trees of *Acacia nilotica,* 8 of *Acacia albida,* 12 of *Acacia tortilis* and 9 of *Prosopis cineraria* were felled flush with the ground to determine volume of main stem and green biomass weight of the entire above ground portion of the tree.

Diameter at breast height (dbh) was recorded for each tree. After felling total height was determined. Then stem was debranched and its height upo to 5 cm diameter at thin end was measured. The main stem was converted into 2-3 m long logs. Mid-diameter of each log was found out to compute the volume of the main stem by Huber formula. For weight measurements, the main stem was converted into logs of approximately 2 m length and their green weight was recorded. The branches were bundled together and weighed separately. In all, the following data were recorded/calculated for each tree: dbh (cm), total height (m), stem volume (m^3) and green stem weight (kg) up to 5 cm thin end diameter, branch weight (kg) and total weight (kg). The branch wood of more than 5 cm diameter at thin end was included in the main stem. Air dry weight of main stem and branches was found after 3 months.

Analysis of data

For each species following mathematical models were used for estimation of stem weight, branch weight, and total weight separately (3).

Parabolic $Y = a + bD + cD^2$ (i)

Cubic $Y = a + bD + cD^2 + dD^3$ (ii)

Allometric D $Y = aD^b$ or $\log Y = \log a + b \log D$ (iii)

Exponential $Y = ae^{bD}$ or $\log Y = \log a + bD$ (iv)

Allometric combined variable D^2H $Y = a(D^2H)^b$ or $\log Y = \log a + b \log(D^2H)$ (v)

Where Y = Stem weight, branch weight or total weight in kg
D = Diameter breast height in cm
H = Height in metres
a, b, ... are regression constant and co-efficients. Log is the natural log i.e. to the base e

Again the above models were applied for estimation of total weight (Y), using volume of main stem (V) and V^2H as dependent variables separately as follows:

$Y = a + bV + cV^2$ (vi)

$Y = a + bV + cV^2 + dV^3$ (vii)

$Y = aV^b$ or $\log Y = \log a + b \log V$ (viii)

$Y = ae^{bV}$ or $\log Y = \log a + bV$ (ix)

$Y = a(V^2H)^b$ or $\log Y = \log a + b \log(V^2H)$ (x)

Results and Discussion

The ratio between air dry weight (measured after 3 months of felling) and green weight of stem wood ranged between 0.60 to 0.65 for *Acacia nilotica, Acacia tortilis* and *Prosopis cineraria*. In other words, the air dry weight of stem wood turned out to be approximately two third of green weight. The same ratio was obtained for branch wood. However, for *Acacia albida* the ratio for stem wood and branch wood was about 0.50 i.e. air dry weight was half of green weight.

It was found that there was no significant difference between biomass (green weight of stem and branches) of different seedlots of one species so the data were combined for each species for estimation of biomass weight. Details of felled tree of different seedlots of each species are given in Appendix I.

Regression equations developed from the above models for each species are given below:

A. Species: *Acacia nilotica*

(a) Stem weight

$$Y = 8.3201 - 2.9914D + 0.3998D^2 \quad \text{(xi)}$$

$$Y = -67.4193 + 22.3054D - 2.3454D^2 + 0.0969D^3 \quad \text{(xii)}$$

$$\log Y = -3.6639 + 2.8457 \log D \quad \text{(xiii)}$$

$$\log Y = -0.2552 + 0.3104D \quad \text{(xiv)}$$

$$\log Y = -3.8483 + 1.0313 \log D^2H \quad \text{(xv)}$$

(b) Branch weight

$$Y = 22.9426 - 4.2873D + 0.4399D^2 \quad \text{(xvi)}$$

$$Y = 21.0193 - 3.6783D + 0.3739D^2 + 0.0023D^3 \quad \text{(xvii)}$$

$$\log Y = -0.9196 + 1.7692 \log D \quad \text{(xviii)}$$

$$\log Y = 1.1721 + 0.1960D \quad \text{(xix)}$$

$$\log Y = -0.8817 + 0.1666 \log D^2H \quad \text{xx)}$$

(c) Total weight

$$Y = 31.1627 - 7.2787D + 0.8397D^2 \quad \text{(xxi)}$$

$$Y = -46.4000 + 18.6271D - 1.9716D^2 + 0.0992D^3 \quad \text{(xxii)}$$

$$\log Y = -1.2167 + 2.1490 \log D \quad \text{(xxiii)}$$

$$\log Y = 1.3367 + 0.2367D \quad \text{(xxiv)}$$

$$\log Y = -1.2989 + 0.7697 \log D^2H \quad \text{(xxv)}$$

$$Y = 6.5286 + 1507.4304V - 3437.2483V^2 \quad \text{(xxvi)}$$

$$Y = -23.5750 + 6234.4927V - 212471V^2 + 2699776V^3 \quad \text{(xxvii)}$$

$$\log Y = 6.7187 + 0.8116 \log V \quad \text{(xxviii)}$$

$$\log Y = 2.7046 + 36.5037V \quad \text{(xxix)}$$

$$\log Y = 5.6585 + 0.3547 \log V^2H \quad \text{(xxx)}$$

Stem Weight (SW) Models

Out of the five models tested, allometric model with D^2H as independent variable yielded better estimates than other models on the basis of 'F' value, root mean square error and coefficient of correlation within the range of data as shown below. However, this was not selected because it involved estimation of height for different diameter classes which was subsequently used for further estimation. An accurate measurement of height of standing trees of *Acacia nilotica* is very difficult due to their spreading crown. Of the remaining four models, quadratic and cubic models gave nonsignificant regression constants and regression coefficient and were, therefore, rejected. Similarly, the regression constant or intercept of the exponential model was found to be nonsignificant. Furthermore its estimates beyond the range tuned out to be unrealistic due to its exponential nature. The indices of best fit for allometric models are shown below:

F value	=	135.485 *
Root mean square error (RMSE)	=	0.2655
Coefficient of correlation (R)	=	0.902 *

This model was further compared with the following three models:

1. $Y = a + bD$ or $Y = -25.5906 + 4.5031D$

This model yielded good results within the range but being linear in nature did not depict the bilogical phenomenon of biomas growth.

2. $Y = D^b$ or $Y = D^{1.1844}$ or $\log Y = 1.1844 \log D$

This allometric model without intercept (a) was tested but it behaved like the linear model as described above.

* Significant at 0.01 level

3. $Y = e^{bD}$ or $Y = e^{0.2833D}$ or $\log Y = 0.2833D$

This exponential model without intercept (a) gave very high estimates beyond the range of data. Foe example estimate of 4907 kg was obtained for dbh of 30 cm.

Ultimately the allometric model given in (xiii) above i.e. $\log Y = -3.6639 + 2.8457 \log D$ was selected for estimation of stem biomass.

Branch Weight (BW) and Total Weight (TW) Models

The above procedure was followed for selection of models for branch weight and total weight respectively. In both the cases exponential model gave better estimates within the range of data but yielded unrealistic estimates beyond the range and hence rejected. Other models except allometric, behaved similarly as described above and were not seleted. The following allometric equations were finally selected for estimation:

(i) Branch weight equation (xviii)

$\log Y = -0.9196 + 1.7692 \log D$
F value = 26.899*, RMSE = 0.3704, R = 0.682*

(ii) Total weight equation (xxiii)

$\log Y = -1.2167 + 2.1490 \log D$
F value = 60. 826*, RMSE = 0.2992 R = 0.814*

As for estimation of total weight using volume (V) as independent variable, again allometric equation (xxviii) i.e. $\log Y = 6.7187 + 0.8116 \log V$ yielded better results than other models with F value = 91.114*, RMSE = 0.2595 and R = 0.864*. The estimates were closer to the above equation (xxiii) in which only D is used as independent variable. However, ease in measurement of dbh for estimation of total weight, equation (xxiii) was preferred over the volume model i.e. equation (xxviii).

Allometric model has been found to be suitable for determining biomass for different components of a tree e.g. brushwood and stemwood with the help of dbh and height (2). This growth model, therefore, is widely accepted for estimation of biomass. Its significance lies in describing the constant 'a' as 'initial growth index' giving the value of Y when the value of estimator or predictor (D in present case) is unity. The value of 'b' is termed as 'equilibrium constant' or 'growth ratio constant' and is of biological significance in the growth model (7).

Estimates for stem weight, branch weight and total weight up to 30 cm diameter class with one cm class interval are given in Appendix II.

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* Significant at 0.01 level

B. Species: *Prosopis cineraria*

Only data from 9 trees with dbh from 4.1 cm to 11.1 cm could be obtained. However, all the models as applied to *Acacia nilotica* were used. For stem weight and branch weight both exponential and allometric (with D^2H as independent variable) models behaved similarly. Both had to be rejected on the grounds mentioned in the case of *Acacia nilotica*. Nevertheless, allometric model showed logical estimates and hence was selected for stem weight, branch weight and total weight.

The regression equations are:

(a) Stem weight

$$\log Y = -2.8335 + 2.1896 \log D$$
F value = 24.520*, RMSE = 0.3602 R = 0.882*

(b) Branch weight

$$\log Y = -3.1075 + 2.3390 \log D$$
F value = 22.383*, RMSE = 0.4027 R = 0.873*

(c) Total weight

$$\log Y = -2.2659 + 2.2630 \log D$$
F value = 26.935*, RMSE = 0.3552 R = 0.891*

For total weight, allometric model with volume (V) used as independent variable i.e. $\log Y = 7.2638 + 1.0702 \log V$ with F value = 29.462*, RMSE = 0.3426 and R = 0.899* yielded estimates closer to the model (c) above using D as estimating variable. However, the 'D' model is preferred to it for ease in measuring dbh for estimating total biomass in the former.

Estimates upto 20 cm dbh with 1 cm interval for stem, branch and total weight are given separately in Appendix III.

C. Species: *Acacia albida*

Data were collected from 8 trees ranging in dbh from 6.0 to 19.7 cm. All models listed for *Acacia nilotica* data were also used in this case. However, the behaviour of the models was similar to those developed for *Prosopis cineraria* data. Because allometric model found to be accurate within the range of data and reasonable for extrapolation for estimation of stem weight, branch weight and total weight and hence were selected. The regression equations derived from this model for estimation of above attributes are shown below alongwith indices of best fit:

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* Significant at 0.01 level

(a) Stem weight

log Y = −3.6731 + 2.6931 log D
F value = 56.703*, RMSE = 0.4140, R = 0.951*

(b) Branch weight

log Y = −2.9032 + 2.2508 log D
F value = 22.080*, RMSE = 0.5545, R = 0.887*

(c) Total weight

log Y = −2.6322 + 2.4986 log D
F value = 41.370*, RMSE = 0.4497, R = 0.934*

Use of allometric model with volume 'V' as independent variable for total weight yielded results similar to those of *Prosopis cineraria* data. However, from practical point of view of measuring volume first and then using it for estimation precluded its use. Hence estimations were done using dbh (D) i.e. model (c). The estimates up to dbh of 30 cm with 1 cm interval using above model are given in Appendix IV for stem, branch and total weight separately.

D. Species: *Acacia tortilis*

The data were collected from 12 trees with dbh range of 4.8 cm to 22.3 cm. All models used for above species were also tested with this data. The allometric model showed superiority over others in this case as well. The following regression equations were considered suitable for estimation:

(a) Stem weight

log Y = −2.5195 + 2.3221 log D
F value = 284.427*, RMSE = 0.2228, R = 0.983*

(b) Branch weight

log Y = −3.0091 + 2.5090 log D
F value = 434.030*, RMSE = 0.1949, R = 0.989*

(c) Total weight

log Y = −2.0572 + 2.4107 log D
F value = 366.722*, RMSE = 0.2037, R = 0.987*

* Significant at 0.01 level

Estimation of total weight by using volume (V) in the allometric model was again similar to that of dbh (D). Yet from practical considerations use of latter variable was preferred. Estimates based on the use of dbh (D) upto 30 cm dbh with 1 cm interval for stem, branch and total weight are given separately in Appendix V.

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APPENDIX-I

DETAILS OF FELLED TREES OF DIFFERENT SEED LOTS OF EACH SPECIES

SPECIES: *ACACIA NILOTICA*

S. No.	Source/Seedlot/Origin	Diameter (cm)	Height (m)	Stem Length (m)	Volume (m^3)	Stem weight (kg)	Branch weight (kg)	Total weight (kg)
1.	S1/1069/Uttar Pardesh India	10.8	7.8	5.90	0.037	15	14	29
2.	S1/1069/Uttar Pardesh India	6.7	6.5	3.30	0.012	10	9	19
3.	S1/1069/Uttar Pardesh India	12.2	8.1	5.00	0.043	33	35	68
4.	S2/1070/Maharashtra India	10.8	5.8	3.15	0.021	16	18	34
5.	S2/1070/Maharashtra India	7.3	5.8	2.50	0.010	5	14	19
6.	S2/1070/Maharashtra India	9.5	5.8	2.30	0.016	18	20	38
7.	S3/1071/Maharashtra India	6.4	6.5	2.40	0.008	4	14	18
8.	S3/1071/Maharashtra India	7.0	6.2	2.70	0.010	9	37	46
9.	S3/1071/Maharashtra India	11.8	7.7	6.50	0.043	33	35	68
10.	S3/1071/Maharashtra India	8.6	6.5	2.60	0.014	11	15	26
11.	S4/1080/Andhra Pardesh India	10.3	5.5	2.70	0.023	19	38	57
12.	S4/1080/Andhra Pardesh India	7.9	6.0	3.90	0.012	8	9	17
13.	S4/1080/Andhra Pardesh India	9.5	6.0	3.40	0.020	14	20	34
14.	S5/1081/Haryana India	8.4	5.0	3.40	0.017	10	18	28
15.	S5/1081/Haryana India	10.5	8.5	5.60	0.031	20	27	47
16.	S5/1081/Haryana India	9.5	8.7	6.40	0.033	22	18	40
17.	S6/1082/Maharashtra India	7.9	4.8	2.30	0.011	6	14	20
18.	S6/1082/Maharashtra India	6.4	4.7	2.30	0.009	5	12	17
19.	S6/1082/Maharashtra India	8.3	4.6	2.30	0.013	9	18	27
20.	S6/1082/Maharashtra India	6.7	4.5	2.00	0.007	4	7	11

21.	S7/1171/Muzaffargarh Pakistan	10.2	6.9	4.70	0.027	19	22	41
22.	S8/1170/Dargai Pakistan	7.9	4.5	1.90	0.023	18	32	50
23.	S8/1170/Dargai Pakistan	7.9	5.7	3.40	0.013	9	14	23
24.	S8/1170/Dargai Pakistan	12.6	6.9	4.60	0.040	34	36	70
25.	S9/1169/D.G. Khan Pakistan	9.9	6.5	4.60	0.036	20	36	56
26.	S9/1169/D.G. Khan Pakistan	9.2	6.5	3.20	0.020	14	18	32
27.	S9/1169/D.G. Khan Pakistan	7.9	5.8	3.20	0.011	7	8	15
28.	S10/1168/Pattoki Pakistan	9.5	7.3	4.20	0.027	18	23	41
29.	S10/1168/Pattoki Pakistan	10.2	7.5	2.80	0.026	19	32	51
30.	S11/Control/Gadani Pakistan	9.5	7.4	3.90	0.021	20	27	47
31.	S11/Control/Gadani Pakistan	12.4	9.0	5.50	0.045	33	43	76
32.	S11/Control/Gadani Pakistan	8.3	6.6	2.95	0.016	15	16	31
33.	S11/Control/Gadani Pakistan	7.9	6.1	3.00	0.012	9	11	20
	SPECIES: ***PROSOPIS CINERARIA***							
1.	S2/1088/Uttar Pardesh India	7.0	4.2	2.3	0.007	4	7	11
2.	S3/1090/Rajasthan India	9.5	4.0	2.2	0.015	7	8	15
3.	S3/1090/Rajasthan India	11.1	5.5	3.4	0.260	18	16	34
4.	S3/1090/Rajasthan India	7.0	4.3	2.9	0.008	4	5	9
5.	S3/1090/Rajasthan India	6.4	4.1	2.5	0.006	4	3	7
6.	S8/1182/Saeedabad Pakistan	6.0	3.5	2.0	0.006	2	2	4
7.	S9/1180/Bahawalpur Pakistan	5.7	2.8	1.9	0.007	3	2	5
8.	S10/1181/Bahawalpur Pakistan	6.4	3.1	2.0	0.006	2	2	4
9.	S13/Control Gadani Pakistan	4.1	3.6	2.0	0.003	2	2	4
	SPECIES: ***ACACIA ALBIDA***							
1.	Source: Senegal	14.3	6.1	6.70	0.039	27	14	41
2.	Seedlot No. 1043 & 1044	9.2	4.4	2.70	0.019	6	4	10
3.		12.1	6.2	5.00	0.036	24	11	35
4.		7.9	4.1	2.30	0.010	4	4	8

S. No.	Source/Seedlot/Origin	Diameter (cm)	Height (m)	Stem Length (m)	Volume (m³)	Stem weight (kg)	Branch weight (kg)	Total weight (kg)
5.		6.4	4.7	3.00	0.008	5	7	12
6.		6.0	5.0	2.70	0.006	5	4	9
7.		15.9	5.0	2.35	0.047	41	45	86
8.		19.7	9.6	8.65	0.142	116	68	184
		SPECIES:	*ACACIA*	*TORTILIS*				
1.	Source: Israel	4.8	3.8	2.1	0.004	4	3	7
2.	Seedlot No. 1066	6.4	5.7	3.1	0.010	5	4	9
3.		7.9	5.4	2.7	0.012	9	9	18
4.		9.5	6.1	3.2	0.020	14	16	30
5.		11.1	7.2	3.5	0.028	25	23	48
6.		12.7	6.2	3.3	0.032	26	25	51
7.		14.3	8.0	4.9	0.060	47	45	92
8.		15.9	5.9	1.8	0.360	33	36	69
9.		17.5	8.2	2.4	0.054	49	54	103
10.		19.1	9.0	4.2	0.104	90	99	189
11.		20.7	8.5	5.5	0.141	113	106	219
12.		22.3	8.5	4.5	0.136	122	131	253

APPENDIX-II

ESTIMATES OF GREEN BIOMASS OF *ACACIA NILOTICA*

S. No.	DBH (cm)	(A) Stem weight (kg)	(B) Branch weight (kg)	(C) Total weight (kg)
1	1	0.03	0.40	0.30
2	2	0.18	1.36	1.31
3	3	0.58	2.78	3.14
4	4	1.32	4.63	5.83
5	5	2.50	6.87	9.41
6	6	4.20	9.49	13.93
7	7	6.51	12.47	19.40
8	8	9.52	15.79	25.84
9	9	13.31	19.45	33.29
10	10	17.97	23.43	41.74
11	11	23.57	27.74	51.23
12	12	30.19	32.35	61.77
13	13	37.91	37.27	73.36
14	14	46.81	42.50	86.02
15	15	56.96	48.01	99.77
16	16	68.45	53.82	114.62
17	17	81.34	59.91	130.57
18	18	95.70	66.29	147.63
19	19	111.62	72.94	165.82
20	20	129.16	79.87	185.14
21	21	148.40	87.07	205.61
22	22	169.40	94.54	227.23
23	23	192.25	102.28	250.00
24	24	217.00	110.28	273.95
25	25	243.73	118.54	299.07
26	26	272.51	127.06	325.37
27	27	303.40	135.83	352.85
28	28	336.49	144.86	381.54
29	29	371.82	154.13	411.42
30	30	409.48	163.66	442.51

A Derived from $\text{Log } Y = -3.6639 + 2.8457 \text{ Log } D$

B Derived from $\text{Log } Y = -0.9196 + 1.7692 \text{ Log } D$

C Derived from $\text{Log } Y = -1.2167 + 2.1490 \text{ Log } D$

APPENDIX-III

ESTIMATES OF GREEN BIOMASS OF *PROSOPIS CINERARIA*

S. No.	DBH (cm)	(A) Stem weight (kg)	(B) Branch weight (kg)	(C) Total weight (kg)
1	1	0.06	0.00	0.10
2	2	0.27	0.00	0.50
3	3	0.65	0.04	1.25
4	4	1.22	0.23	2.39
5	5	1.99	0.58	3.96
6	6	2.97	1.14	5.98
7	7	4.17	1.93	8.48
8	8	5.58	2.95	11.47
9	9	7.22	4.24	14.98
10	10	9.10	5.79	19.01
11	11	11.21	7.63	23.58
12	12	13.56	9.76	28.72
13	13	16.16	12.20	34.42
14	14	19.01	14.95	40.70
15	15	22.11	18.03	47.58
16	16	25.47	21.44	55.06
17	17	29.08	25.19	63.16
18	18	32.96	29.30	71.88
19	19	37.10	33.76	81.24
20	20	41.51	38.59	91.24

A Derived from $\text{Log } Y = -2.8335 + 2.1896 \text{ Log } D$
B Derived from $\text{Log } Y = -3.1075 + 2.3390 \text{ Log } D$
C Derived from $\text{Log } Y = -2.2659 + 2.2630 \text{ Log } D$

APPENDIX-IV

ESTIMATES OF GREEN BIOMASS OF *ACACIA ALBIDA*

S. No.	DBH (cm)	(A) Stem weight (kg)	(B) Branch weight (kg)	(C) Total weight (kg)
1	1	0.03	0.05	0.07
2	2	0.16	1.26	0.41
3	3	0.49	0.65	1.12
4	4	1.06	1.24	2.30
5	5	1.94	2.05	4.01
6	6	3.17	3.09	6.33
7	7	4.79	4.38	9.30
8	8	6.87	5.91	12.98
9	9	9.43	7.71	17.42
10	10	12.53	9.77	22.67
11	11	16.19	12.11	28.77
12	12	20.47	14.73	35.75
13	13	25.40	17.64	43.67
14	14	31.00	20.84	52.55
15	15	37.34	24.34	62.44
16	16	44.42	28.14	73.36
17	17	52.30	32.26	85.36
18	18	61.01	36.69	98.46
19	19	70.57	41.44	112.71
20	20	81.02	46.51	128.12
21	21	92.40	51.90	144.73
22	22	104.73	57.63	162.57
23	23	118.05	63.70	181.66
24	24	132.39	70.10	202.04
25	25	147.77	76.85	223.74
26	26	164.23	83.94	246.78
27	27	181.80	91.38	271.18
28	28	200.51	99.18	296.97
29	29	220.38	107.33	324.19
30	30	241.45	115.84	352.85

A Derived from Log Y = $-3.6731 + 2.6931$ Log D
B Derived from Log Y = $-2.9032 + 2.2508$ Log D
C Derived from Log Y = $-2.6322 + 2.4986$ Log D

APPENDIX-V

ESTIMATES OF GREEN BIOMASS OF *ACACIA TORTILIS*

S. No.	DBH (cm)	(A) Stem weight (kg)	(B) Branch weight (kg)	(C) Total weight (kg)
1	1	0.08	0.05	0.13
2	2	0.40	0.28	0.68
3	3	1.03	0.78	1.81
4	4	2.01	1.60	3.61
5	5	3.38	2.80	6.19
6	6	5.16	4.42	9.60
7	7	7.38	6.51	13.93
8	8	10.07	9.10	19.22
9	9	13.23	12.23	25.52
10	10	16.90	15.93	32.91
11	11	21.09	20.23	41.41
12	12	25.81	25.17	51.07
13	13	31.08	30.76	61.94
14	14	36.92	37.05	74.05
15	15	43.33	44.05	87.45
16	16	50.34	51.80	102.17
17	17	57.95	60.31	118.25
18	18	66.17	69.61	135.72
19	19	75.02	79.72	154.62
20	20	84.51	90.67	174.97
21	21	94.65	102.47	196.81
22	22	105.45	115.16	220.17
23	23	116.91	128.75	245.07
24	24	129.06	143.26	271.55
25	25	141.89	158.71	299.63
26	26	155.42	175.12	329.34
27	27	169.65	192.51	360.71
28	28	184.60	210.90	393.76
29	29	200.28	230.31	428.52
30	30	216.68	250.76	465.01

A Derived from $\text{Log } Y = -2.5195 + 2.3221 \text{ Log } D$
B Derived from $\text{Log } Y = -3.0091 + 2.5090 \text{ Log } D$
C Derived from $\text{Log } Y = -2.0572 + 2.4107 \text{ Log } D$