RESEARCH NOTE

Aboveground biomass tables for *Azadirachta indica* a. Juss.

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SUMMARY

Neem is a multipurpose tree species and each part of this tree has one or several uses. Equations for green and dry biomass based on diameter at breast height and total tree height are reported.

Keywords: biomass table, neem, semi-arid region, India.

INTRODUCTION

Neem (*Azadirachta indica* A. juss) is one of India's most useful multipurpose tree species for both rural and urban people. Almost all parts of the tree have one or more uses. The wood strength properties compare favourably with those of teak. The wood is valued for household furniture, carts, yokes, boards and panels, agricultural implements, etc. Small branches and twigs provide firewood. Small twigs are also used as tooth brushes. Leaves are considered good fodder for cattle and goats. They are also used as manure. Neem leaves also have several medicinal properties and are used as an insect repellent and in the control of nematodes. The pulp of ripe fruit is used as tonic, purgative, emollient and anthelmintic. Azadirachtin, nimbin and saponin are some of the major active components isolated from neem. The seed kernel is used as an insecticide and has been found effective against a large number of insects. The kernel also yields oil, commercially known as margosa oil, which is mainly used in the making of soap and of toothpaste. The bark of the tree is used for various medicinal purposes, primarily anti-protozoal, anti-allergic, anti-dermatitic and anti-fungal. Most recently the anti-spermicidal properties of neem products have also been identified.

Although volume is the most generally accepted variable for measuring forest growth, there are advantages to a weight-based approach. The value of wood for fuelwood, pulp and paper and many other uses is much more closely related to the weight (biomass) than the volume (Spurr 1952). Bark, leaves and twigs, and seeds are also sold by weight. Though there is a report on volume tables for neem from India (Jain *et al.* 1997), we are not aware of any report on the biomass tables for the species in the literature.

It is in this context that the present study was initiated to predict aboveground biomass of various parts of neem in relation to the diameter at breast height (D) and total tree height (H).

Neem is neither a tree of natural forests nor does it play a major part of plantation forestry in the tropics. It is mainly planted as a shade tree, avenue tree and around homesteads. Therefore single stem based biomass tables were preferred in the present study rather than a per unit area based approach.

MATERIALS AND METHOD

Though neem is grown mainly an avenue tree, destructive sampling for the purpose of weight data collection was not possible from such a population as felling of avenue trees is not permissible. Hence samples had to be collected from plantations raised by forest departments. Accordingly, 5 sample plots covering various ages and spacings were selected in Gandhinagar (23° 5' N - 23°2' N and 72°32'E - 72°48' E), Gujarat State. These plots are permanent in nature and have been established for the study of growth and yield. This region falls under the hot semi-arid eco-region (agro-ecoregion 5) which is characterisd by 500-1000 mm of annual precipitation and an annual PET demand of 1600-2000 mm according to the National Bureau of the Soil and Land Use Planning of Indian Council of Agricultural Research (1992). The average rainfall of Gandhinagar is 928 mm and the site is located at an altitude of about 55 m. Temperatures vary between 48°C and 25°C in summer and between 27°C and 12°C in winter. The soils of the region are gravelly loam to clayey loam in texture. The details of the plots laid out are given in Table 1.

TABLE 1 *Details of the plots*

Spacing [a] (m)	Age (years)	Plot size (m2	Mean DBH (cm)	Mean height (m)	No. of trees measured
4 x 4	23	709	18.8	12.2	30
5 x 3	20	675	16.4	10.9	32
5 x 3	17	633	14.0	10.4	48
3 x 3	15	562	14.3	9.9	45
2 x 2	4	263	4.7	5.1	82

Note a: spacing adopted at the time of establishment

Diameter at breast height (D) and total tree height (H) of all trees within the sample plots were measured. Trees were then stratified into different diameter classes in each plot. A sub-sample of trees was felled in the surround of each of the plots (to keep the permanent sample plots undisturbed) representing different diameter classes within the particular plot. These were then measured for D, H, green weights of stem-wood, branches and leaves and twigs. Trees with multiple stems were treated as separate trees. Data were collected in this manner from 30 trees (6 trees from the surround of each plot). The values of D and H in the sample plots ranged from 5.4 cm to 35.8 cm and 4.5 m to 16.2 m, respectively, while the ranges of these values for felled trees were from 7 cm to 35.6 cm and 6 m to 15.4 m, respectively, indicating that the trees felled for destructive sampling were representative of the population.

The number of trees necessary for a weight table for a given species is a critical question. Estimates from many recent biomass studies suggest that 30-100 trees are enough for a regional table using stratified sampling of the population. There is evidence that, if sample trees are selected in equal or near equal numbers in each size class, 30 trees for an individual tree biomass table are adequate (MacDicken *et al.* 1991). The stems and branches of the felled trees were divided into logs of 3m length and their leaves and twigs were separated. The green weights of each of these were then measured in the field itself. Small representative samples of wood from both the ends of each log and leaves and twigs were collected and their green weights recorded. Oven dry weights were determined for these samples in the laboratory. Based on these two (green and dry) sample weights, dry weights for each tree were calculated.

The data from the destructive sampling were used to find allometric relationships for biomass as functions of D and H.

RESULTS

The green and dry weights of total biomass (stem+branches+leaves+twigs), total wood (stem+branches), stem wood, branch wood, bark and leaves and twigs were regressed on D and H to give the biomass equations shown in Table 2. Step-wise regressions using an SPSS package were fitted to select independent variables on the basis of increasing values of F. Best models were selected on the basis of significance of partial regression coefficients at the P = 0.05 level, highest F-value, high R^2 and low standard error of estimate (SEE). The dependent variables are weights of over-bark wood. Similar equations were derived for under-bark wood biomass: these are not reported here.

TABLE 2 *Regressions for green and dry weights of components of biomass over-bark*

Variable	const.	D^2	DH	D^2H	H^2	R^2	F-ratio **
GREEN WEIGHTS							
stem	9.610			0.024		0.978	839.82
	(4.217)			(0.001)			
branches	-0.744	0.692	-0.930			0.970	179.02
	(18.028)	(0.100)	(0.255)				
total wood	-20.687			0.047		0.989	1683.34
	(5.666)			(0.001)			
leaves,twigs	-5.371	0.233				0.824	89.14
	(9.692)	(0.025)					
total biomass	1.409	1.382	-1.219			0.992	1073.42
	(14.573)	(0.103)	(0.249)				
DRY WEIGHTS							
stem	5.923			0.017		0.973	695.56
	(3.186)			(0.001)			
branches	-1.394	0.477	-0.638			0.974	206.81
	(11.633)	(0.065)	(0.164)				
total wood	8.690			0.036	-0.3600	0.996	2307.38
	(5.675)			(0.001)	(0.077)		
leaves, twigs	-3.744	0.106				0.808	80.01
	(4.649)	(0.012)					
total biomass	-13.410			0.040		0.985	1232.25
	(5.636)			(0.001)			

Notes: standard errors of regression coefficients are shown in parentheses.
** Pr ≤ 0.0001

Since the bark is used for various medicinal purposes, it was considered useful to derive equations for bark biomass too. Results are shown in Table 3.

TABLE 3 *Coefficients and summary statistics for bark biomass equations*

Variable	Const.	D^2H	Mean weight (kg/tree)	SEE	R^2	F-ratio **
GREEN						
	-3.601 (1.241)	0.009 (0.000)	27.89	4.14	0.986	1365.68
DRY						
	- 2.719 (0.860)	0.006 (0.000)	16.69	2.87	0.983	1081.75

Note: ** Pr ≤ 0.0001

The F-values in both tables show highly significant levels of results for all regressions. The values of standard errors show that all the partial regression coefficients are significant. The average bias detected from the plots of the residuals against the measured data is almost negligible (of the order of 10^{-14}).

DISCUSSION

Biomass data for neem trees were available for five different ages covering four different plantation spacings. The biomass equations for each component of the tree were derived independently. The component predictions are not additive (Kozak 1970).

The resulting equations should be applied only to the region in which sample plots were laid out for data collection. The site appears to be typical of similar sites in India and it may be considered that these equations could be used more widely, though with caution.

Some of the limitations of the study are:

1. Seeds have not been included as one of the yields.
2. The plantations were raised by the State Forest Department and no spacing trial was laid out as such on some specific design. Hence, the effect of spacing on biomass yield per ha could not be assessed.
3. No data based on short rotation copice production were available for analysis.

CONCLUSION

The stated objectives were fulfilled. Regression equations for predicting biomass yield have been derived. These are local biomass functions, which should be applied with caution in other parts of India.

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