

Hardwickia binata

Total biomass = $0.0938 \cdot D^{2.5247}$ $R^2 = 0.951$, MSE = 48.7999
Above biomass = $0.0731 \cdot D^{2.5419}$ $R^2 = 0.952$, MSE = 32.5948
Below biomass = $0.0157 \cdot D^{2.55726}$ $R^2 = 0.937$, MSE = 6.0252

(Biomass equations based on 17 years old plantation at Jodhpur. DBH and height ranged from 4.45-17.5 cm and 3.25-9.10 m, respectively).

Colophospermum mopane

Total biomass = $7.0170 \cdot \exp^{0.1672 \cdot D}$ $R^2 = 0.898$, MSE = 0.692657
Above biomass = $0.1742 \cdot D^{2.2407}$ $R^2 = 0.889$, MSE = 59.2391
Ln Below biomass = $-0.2537 + 0.4057 \cdot D + 2.5887 \cdot \ln(D) \cdot D$ $R^2 = 0.728$, MSE = 0.01589

(Biomass equations based on 17 years old plantation at Jodhpur. DBH and height ranged from 2.9-17.5 cm and 3 - 6.2 m, respectively).

Calligonum polygonoides

Stem biomass = $1.02524 + 16.7264 \cdot (\log D)^{6.289669}$
Above biomass = $1.220309 + 20.691679304 \cdot (\log D)^{5.436036}$
Below biomass = $1.241631 + 10.219185 \cdot (\log D)^{3.869759}$
Total biomass = $2.484028 + 30.373021 \cdot (\log D)^{4.756885452}$

(Biomass equations based on data collected from 8 arid districts of Rajasthan. DBH and height ranged from 1.1-8.25 cm and 0.35 – 3.15 m, respectively)

Mixed tree species

Total biomass = $0.265851100 \cdot D^{2.0499383}$
Above biomass = $0.181494261 \cdot D^{2.058650773}$
Root biomass = $0.084773863 \cdot D^{2.028825779}$

(Biomass equations based on 291 trees of 39 species across the Rajasthan. Total tree height was between 2.35 and 17.2 m and Dbh between 3.2 to 52.50 cm, Total dry biomass ranged from 0.56 to 839.30 kg tree⁻¹, above ground biomass ranged from 0.31 to 585.12 kg tree⁻¹ and root biomass ranged from 0.10 to 254.18 kg tree⁻¹ of felled trees).

Mixed shrub species

Total biomass = $2.643968 - 1.674535 D + 0.3374487 D^2$
Above biomass = $1.422873 - 0.909824 D + 0.199237 D^2$
Root biomass = $1.221440 - 0.764804 D - 0.138231 D^2$

(Biomass equations based on 271 plants of 17 shrub species across the Rajasthan. Collar diameter of shrub ranged from 1.60 to 13.30 cm).

Azadirachta indica

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 for *A. indica*. The equations obtained for various parts of the trees are as follows:

Green weight equations:

Stem = $9.61 + 0.024 \cdot D^2 H$
Branch = $-0.744 + 0.692 \cdot D^2 - 0.93 \cdot DH$
Total wood = $-20.687 + 0.047 \cdot D^2 H$
Leaves & twigs = $-5.371 + 0.233 \cdot D^2$
Total biomass = $1.409 + 1.382 \cdot D^2 - 1.219 \cdot DH$

Dry weight equations:

Stem = $5.923 + 0.017 \cdot D^2 H$
Branch = $-1.394 + 0.477 \cdot D^2 - 0.638 \cdot DH$
Total wood = $8.69 + 0.036 \cdot D^2 H - 0.36 \cdot H^2$
Leaves & twigs = $-3.744 + 0.16 \cdot D^2$
Total biomass = $-13.41 + 0.04 \cdot D^2 H$

(Biomass equations based on data from north Gujarat. DBH, height and age ranged from 4.71-21.37 cm, 4.66-12.75 m and 4-28 years, respectively).

AFRI developed volume and biomass equations may be applied on any population of these species available in the study area or in the areas having similar growing conditions. The volume and biomass equations are enormously useful in estimating above-ground total carbon stock and in preparation of carbon tables. The equations could be used more widely, though with carefully.

Volume equations were developed by Dr. V.P. Tewari, Retired Scientist-G & Dr. Bilas Singh and Biomass equations were developed by Dr. G. Singh, Retired Scientist-G & Dr. Bilas Singh.



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Developed Volume and Biomass Allometric Equations of Different Tree Species for Rajasthan and Gujarat



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Volume and biomass allometric equations are essential tools to determine forest productivity and enable forest managers to make informed decisions on forest management. Allometric equations for predicting wood volume and biomass play a critical and clear role in the management of any silvicultural system. Such information is necessary to develop and implement management plans geared towards the harvest and utilization of wood products. Equations that provide accurate predictions of volume and biomass without local bias over the entire range of diameter are one of the basic building blocks of a forest growth and yield model system. However, volume and biomass estimation equations are scarce forestry tree species in Rajasthan and Gujarat state. This limits our knowledge of the standing volume of wood, biomass, and carbon stock of the forests therein. Volume equations developed by AFRI for the pure even-aged stands of *Dalbergia sissoo*, *Eucalyptus camaldulensis*, *Tecomella undulata*, *Prosopis cineraria* and *Ailanthus excelsa* available in IGNP area of Rajasthan and *Acacia nilotica*, *E. Hybrid* and *Tectona grandis* planted in Gujarat have been described here. The accurate estimation of tree biomass is needed for sustainable planning of forest resources and for studies on the energy and nutrients flows in ecosystems. Biomass equations for *Prosopis juliflora*, *Hardwickia binata*, *Colophospermum mopane* and 39 mixed tree species and shrub mixed species in Rajasthan and *Azadirachta indica* planted in Gujarat has been also reported.

Total wood volume equations

AFRI developed allometric equations of forest plantation species for Rajasthan and Gujarat are described here, where, V is the total wood volumes (m³) over-bark, D is the dbh (cm) and H is the total tree height (m).

Vachellia tortilis (Syn. *Acacia tortilis*)

$$V = -0.09415 + 0.0253594 * D$$

$$V = 0.02179 + 0.00003451 * D^2 H + 0.0001990 * D H$$

(Volume tables and equation based measurement of 40 felled trees. The diameter and height ranged from 11-30 cm and 6-14 m, respectively).

Eucalyptus camaldulensis

$$V = 0.000169 * D^{2.41298} \quad \text{Adj. } R^2 = 0.995; \text{ RMSE} = 0.02922$$

$$V = -0.00226 + 0.0000333 * D^2 H \quad \text{Adj. } R^2 = 0.990; \text{ RMSE} = 0.00001$$

(Volume equation based on 91 trees from IGNP area, Rajasthan. DBH, height and age ranged from 5.0- 51.9 cm, 6.6- 26.6 m and 3.0- 28.5 years, respectively).

Dalbergia sissoo

$$V = 0.01328 - 0.00538 D + 0.000760 D^2 \quad \text{Adj. } R^2 = 0.961; \text{ RMSE} = 0.00005$$

$$V = -0.0023 + 0.0000364 D^2 H \quad \text{Adj. } R^2 = 0.992; \text{ RMSE} = 0.00006$$

(Volume equation based on 71 felled trees from IGNP area, Rajasthan. Tree data were .8.2-19.8 m height, 5.8-35.9 cm DBH and 4.2-30.4 years age)

Tecomella undulata

$$V = 0.000088 D^{2.381398} \quad \text{Adj. } R^2 = 0.918; \text{ RMSE} = 0.00803$$

$$V = 0.000066 D^{2.100121} H^{0.553696} \quad \text{Adj. } R^2 = 0.924; \text{ RMSE} = 0.00772$$

(Volume and site index equations based on data from IGNP area, Rajasthan. The felled trees were 5-9.0 m tall, 4.25-22.90 cm in DBH and 15-19 years age)

Prosopis cineraria

$$V = 0.10497 + 0.00544 D + 0.00117 D^2 + 0.000183 D^2 H$$

(Volume equation based on data from IGNP plantation. DBH, height and age ranged from 3.2-36.6 cm, 4.4-15.5 m and 7-25 years, respectively)

Ailanthus excelsa

$$V = 0.03868 + 0.0069 D + 0.00014 D^2 + 0.0000286 D^2 H$$

(Volume equation based on data from IGNP area and Pali division. DBH, height and age ranged from 4.6-40.1 cm, 4.6-16.3 m and 7-18 years, respectively.)

Gujarat state

Azadirachta indica

$$V = 0.07033 - 0.013865 * D + 0.00098532 * D^2 \quad \text{Adj. } R^2 = 0.993,$$

$$\text{RMSE} = 0.022031$$

(Volume equation based on data from North Gujarat. DBH, height and age ranged from 4.71-21.37 cm, 4.66-12.75 m and 4 to 28 years, respectively)

Eucalyptus hybrid

$$V = 0.000076 * D^{2.761477} \quad \text{Adj. } R^2 = 0.978, \text{ RMSE} = 0.02844$$

$$V = 0.000014 * D^{2.141947} H^{1.168588} \quad \text{Adj. } R^2 = 0.989, \text{ RMSE} = 0.02054$$

(Volume equation based on data from Central Gujarat. DBH, height and age ranged from 4.7-33.1 cm, 6.6-27.6 m and 1 to 19 years, respectively)

Vachellia nilotica (Syn. *Acacia nilotica*)

$$V = 0.000071 * D^{2.735778} \quad \text{Adj. } R^2 = 0.975, \text{ RMSE} = 0.03015$$

$$V = 0.000018 * D^{2.363677} H^{0.938962} \quad \text{Adj. } R^2 = 0.983, \text{ RMSE} = 0.02512$$

(Volume equation based on data from Central Gujarat. DBH, height and age ranged from 4.5-31.9 cm, 4.4-17.3 m and 4-21 years, respectively)

Tectona grandis

$$V = 0.000159 * D^{2.419024} \quad \text{Adj. } R^2 = 0.937, \text{ RMSE} = 0.03915$$

$$V = -0.001109 + 0.000039 * D^2 H \quad \text{Adj. } R^2 = 0.955, \text{ RMSE} = 0.03823$$

(Total wood volume equations based on data collected from Central and South Gujarat. DBH, height and age ranged from 7.3-30.8 cm, 8.2-22 m and 14-43 years, respectively.

Biomass equations

The dry weights of total biomass (stem+branches+leaves+twigs) was regressed on diameter at breast height (D) to give the biomass equations for mixed tree species as well individual tree species. The equations obtained for the trees are as follows:

Prosopis juliflora

$$\text{Above ground biomass}(\sqrt{W}) = 0.004534 + 0.500151 * D$$

$$\text{Root biomass (RB)} = 1.850979 + 0.08440 * D^2$$

$$\text{Total biomass (TB)} = 0.405377 D^{1.943568}$$

$$\text{Economic biomass (stem greater than 2 cm dia)} = 0.090651 D^{1.132956}$$

(Biomass equations based on data collected from seven district of Rajasthan DBH and height ranged from 3.10-23.90 cm and 3.10-9.60 m, respectively).