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Technical Note: Predicting the components of aerial biomass of fourwing saltbush from shrub height and volume

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Abstract

Shrub height and crown diameter are useful non-destructive measures of shrub growth, but precise yields of aerial biomass require destructive methods which are unsatisfactory in studies on perennial shrubs. We developed simple regression models to predict components of aerial biomass from the height, crown diameter and volume of 27 unbrowsed shrubs of fourwing saltbush (*Atriplex canescens*). The shrubs, ranging in height from 15 to 110 cm, were cut at ground level and manually separated into forage (leaves) and woody material. Samples were oven-dried. Shrub height and volume were sufficiently precise for predicting components of aerial biomass using exponential and linear regression models, respectively. The precision of these non-destructive measures applied under field conditions to unbrowsed shrubs should be confirmed on browsed shrubs.

Key Words: *Atriplex canescens*, regression models, Balochistan, Pakistan

Saltbushes (*Atriplex* spp.) have considerable potential for providing forage and fuelwood in the arid and semi-arid regions of North Africa and West Asia (Le Houérou 1992, 1995). Fourwing saltbush (*A. canescens*) is a native species of the southwestern U.S.A. with a recognized potential for the semi-arid highlands of Balochistan, a province of Pakistan. This potential was first seen in the mid-1950s when it was first introduced in Balochistan (Shah Rahman, personal communication). It withstands the continental Mediterranean climate of the province, which has cold winters when minimum temperatures can fall to –20° C at altitudes of 1,500-2,500 m, and the hot dry summers when no rain may fall between May and November. The average rainfall in Balochistan increases from about 230 mm in the central area to over 400 mm in the north.

Studies on fourwing saltbush (FWSB) conducted at the Arid Zone Research Institute (AZRI) since 1985 have used shrub height and crown diameter as non-destructive indicators of growth (Aro et al. 1992). However, the yields of leaf and woody biomass are needed for assessing the potential of the saltbush to provide grazing during periods of feed shortages and fuelwood in a province where few forest resources remain. Several workers have shown that aerial biomass can be predicted from shrub height, crown diameter and volume with reasonable levels of precision ($r^2 > 0.9$) using different regression models across a range of species (Le Houérou 1995; Murray and Jacobson 1982; Wilkes 1980). Kessler and Briéde (1985) reported close correlations of aerial biomass and forage/wood ratio with shrub height in *A. nummularia*. They used the volume of a cylinder to describe the volume of this species. The objective of the study reported here was to test simple regression models for predicting aerial biomass of fourwing saltbush from shrub height, crown diameter and volume.

Materials and Methods

Twenty-seven fourwing saltbush shrubs were chosen growing at the AZRI station in Quetta, Balochistan Province (1,650 m altitude, 230 mm mean annual rainfall, 30° 15' N, 67° 25' E). The shrubs were grown from seeds received from the Mastung Station of the Balochistan Forest Department which had obtained the original seeds from the southwestern U.S.A. They ranged from 3-month-old seedlings to mature 3-year-old shrubs of the same genotype. We measured the height (h) of each shrub and made 2 measurements of crown diameter (d_1 and d_2) taken perpendicular to each other at the widest part of the shrub. Shrubs were then cut at ground level and manually separated into leaves and woody material (stems and twigs). The leaves and wood were weighed and subsamples of leaves and chopped wood were oven-dried at 95° C until they reached constant dry weight. The dried biomass of leaf, wood and the sum of these 2 fractions (Y), were related to shrub height, crown diameter $(d_1+d_2)/2$ and volume of an ellipsoid $4/3\pi*(h/2*d_1/2*d_2/2)$ (X) using 3 regression models: 1) $Y = bX$, 2) $Y = a+bX$ and 3) $Y = ae^{bX}$. Results using crown diameter alone as a predictor of biomass are not presented here as crown diameter was a less precise estimator than the other 2 measures.

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Table 1. Prediction of total aerial biomass and the biomass of wood and leaf (Y) from shrub height or volume (X) using different regression models[1].

Model	Y	X	a (s.e.)	b (s.e.)	r^2	Sy.x
1	Total	Height	– – – – –	0.014 (0.0014)	0.796	0.5022
2	Total	Height	–0.689 (0.1776)	0.024 (0.0027)	0.752	0.4000
3	Total	Height	0.045 (0.0142)	0.039 (0.0033)	0.901	0.2560
1	Wood	Height	– – – – –	0.011 (0.0010)	0.803	0.3678
2	Wood	Height	–0.575 (0.1409)	0.019 (0.0021)	0.760	0.2907
3	Wood	Height	0.038 (0.0127)	0.037 (0.0036)	0.878	0.2085
1	Leaf	Height	– – – – –	0.004 (0.0005)	0.692	0.1662
2	Leaf	Height	–0.225 (0.0687)	0.007 (0.0010)	0.633	0.1427
3	Leaf	Height	0.009 (0.0046)	0.042 (0.0055)	0.792	0.1075
1	Total	Volume	– – – – –	2.756 (0.1270)	0.948	0.2540
2	Total	Volume	0.012 (0.0714)	2.732 (0.1854)	0.897	0.2588
3	Total	Volume	0.356 (0.0683)	2.249 (0.2674)	0.788	0.3804
1	Wood	Volume	– – – – –	2.058 (0.0911)	0.952	0.1822
2	Wood	Volume	0.020 (0.0511)	2.021 (0.1327)	0.903	0.1853
3	Wood	Volume	0.267 (0.0490)	2.243 (0.2559)	0.798	0.2730
1	Leaf	Volume	– – – – –	0.698 (0.0606)	0.836	0.1213
2	Leaf	Volume	0.007 (0.0341)	0.711 (0.0885)	0.721	0.1236
3	Leaf	Volume	0.088 (0.0261)	2.266 (0.4107)	0.622	0.1462

[1]The models are: (1) $Y = bX$, (2) $Y = a + bX$, (3) $Y = ae^{bx}$.

Results and Discussion

The range in the height, crown diameter and dry weight of the shrubs was, respectively, 15–110 cm (mean 62 cm, standard deviation (SD) 27.3 cm), 11–135 cm (mean 70 cm, SD 40.3 cm) and 1.8-2994 g (mean 766 g, SD 789.8 g). Components of aerial biomass were closely related to shrub height in a simple non-linear relationship (Fig. 1a), whereas components of aerial biomass were closely and linearly related to shrub volume (Fig. 1b, Table 1). This difference could be accounted for by the crown diameter expanding at a greater rate than the increase in shrub height. Indeed, there was a gradual and linear (r^2 = 0.434, P<0.001) decrease in the ratio of shrub height/crown diameter (Y) as shrub height increased (X). This suggests that for younger, smaller and unbrowsed shrubs a cylinder would be a more appropriate model to predict aerial biomass (Kessler and Briéde 1985), whereas in older shrubs an ellipsoid is more appropriate, as used in this study. Le Houérou (1995) reported linear relationships between bio-volume and total biomass for *A. canescens* but with a lower precision (r^2 =0.80).

Model 1 (see Sy.x in Table 1) predicted the biomass of aerial components from shrub height with marginally less precision than Model 2, whereas both the linear models were less precise predictors of biomass of the different components from shrub height than Model 3. Models 1 and 2 gave similar precision for predicting the components of aerial biomass from shrub volume, and both were more precise than Model 3. Even though it required more measurements, shrub volume was a more precise predictor of biomass, irrespective of the component, than shrub height. The results for Models 1 and 2 (Fig. 1) indicate that the leaf is about one quarter of the total aerial biomass, and its ratio to the woody biomass remains similar irrespective of the height of the shrub.

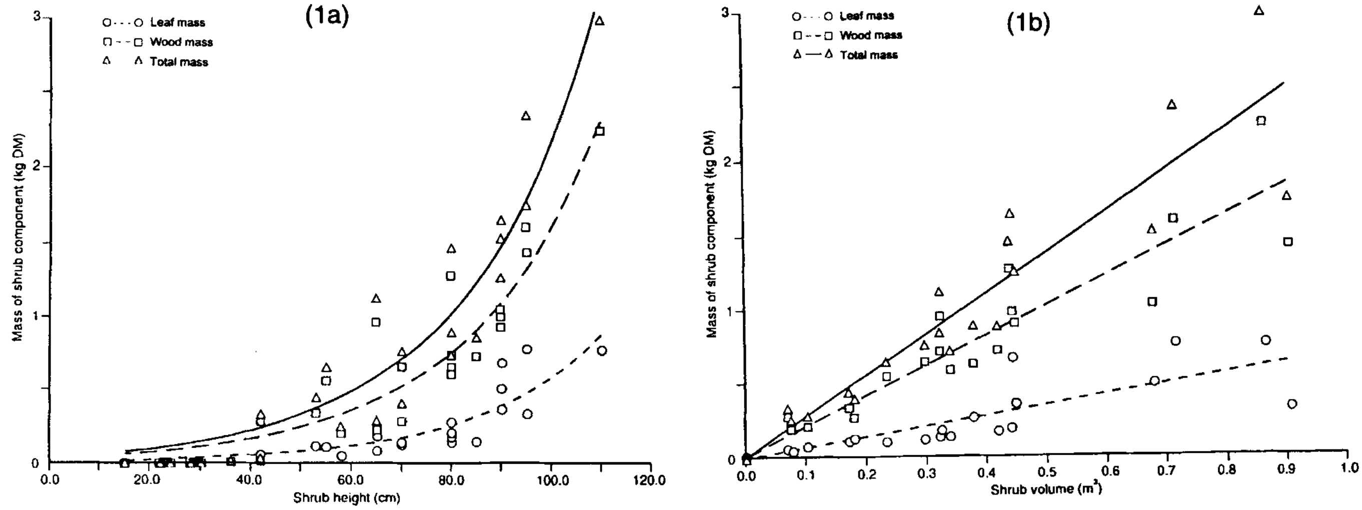

Fig. 1. Relationship between total aerial biomass and biomass of leaf and wood with (1a) height and (1b) volume of fourwing saltbush. (Open symbols refer to raw data points and lines to fitted regressions; see Table 1 for details of the equations.)

Shrub height alone, or combined with crown diameter as shrub volume, can be used to predict the components of aerial biomass with a satisfactory degree of precision for estimating the growth of fourwing saltbush. The degree to which these relationships apply to the different sub-species of fourwing saltbush which have different aerial dimensions and leaf proportions, and the effects of browsing, needs further study.

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