Variability in Predicting Edible Browse from Crown Volume

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Abstract

Biomass estimates were made with regression techniques using crown volume and weight relationships. The log-log function yielded the highest coefficient of determination for Vasey shin oak, plateau oak, Texas persimmon, and honey mesquite. A quadratic function was best for woollybucket bumelia, littleleaf sumac, agarito, and pricklyash. Sugar hackberry showed equally high coefficients with either the linear or quadratic. Coefficients of determination for catclaw acacia, elbowbush, and skunkbush sumac generally were low regardless of the type of regression equation used. When sampled at various periods over the year, predictive accuracy declined for Vasey shin oak and plateau oak through fall and winter but rose again in spring and early summer. For both species, the log-log function was best from late summer to winter but during spring and early summer the quadratic function was best.

Browse biomass commonly is recognized as one of the most difficult of all vegetation components to measure (Blair 1958). Even so, the information has been valuable to foresters for measuring potential flammability (Brown 1976) and to range scientists for estimating utilization by herbivores (Dalrymple et al. 1965; Ferguson and Marsden 1977), forage available to herbivores (Bryant 1977), productivity of herbivores (Leigh et al. 1970), or the response to brush control (Bentley et al. 1970; Scifres et al. 1974). Thus, numerous methods have been developed for inventory of browse or shrub yield. Some of these different methods have been reported by Harniss and Murray (1976).

Recently, techniques used for predicting browse yield have included linear regressions of crown volume on the weight of plants to predict yield. Crown volume requires at least two measurements of the plant in addition to weight, and is well suited because a combination of measurements is usually better than any single measurement (Cook 1960). Also, volume generally yields a better relationship to weight than surface area to weight (Lyon 1968). These volume-weight relationships have usually included only one species (Lyon 1968; Scifres et al. 1974; Rittenhouse and Sneva 1977). Only Bentley et al. (1970) has dealt with more than one shrub species. Previous studies have not examined the same species at different sampling dates within a 1-year period to determine the impact of defoliation on the precision of the predictive equations. Lyon (1968) has, however, found that the precision of regression equations varied with range site for the single species being studied.

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The objective of this research was to evaluate the use of various regression functions for the prediction of biomass from crown volume for several browse species and for selected species at different sampling dates.

Methods and Materials

Crown volume and weight relationships were used on several browse species to estimate the availability of edible browse to herbivores. Two of the species were evaluated at different sampling dates over a 1-year period.

An 8-ha study site was selected at the Texas Agricultural Experiment Station, Sonora, Texas (Fig. 1). The site had been rootplowed 7 years prior. All available browse was in a young age class and less than 2.2 m tall. Since 1970, the browse had received light used by cattle, sheep, Angora goats, and white-tailed deer (*Odocoileus virginianus* L.).

In August, 1975, the density for each species was estimated using either point-center-quarter (Cottam and Curtis 1956) or the corrected-point-distance technique (Laycock and Batcheler 1975), depending on the degree of aggregation. Two transects, 322 m long, were used and points were established every 30.5 m. The distance to the nearest individual of each species was measured and its height and diameter at the widest point were recorded. Height and diameter measurements were converted to conical volume using the formula

$$V = \frac{\pi r^2 h}{3}$$

where r=radius and h=height.

The mean crown volume was calculated for each species on the study site. Conical volume was selected because most species grew in a "V" shape. Sample size used to estimate mean crown volume varied from 11–102 individuals, depending upon the species.

Fig. 1. *Study site at the Texas Agricultural Experiment Station near Sonora, Texas.*

Table 1. Coefficients of determination (r^2 or R^2) and coefficients of variability (*CV*) for twelve browse species sampled in August, 1975, based on various regressions of weight on crown volume.

Species	Sample size	Calculated sample size[a]	Mean weight/plant (g)	Linear r^2	Linear *CV*	Quadratic R^2	Quadratic *CV*	Log-log r^2	Log-log *CV*	Semi-log r^2	Semi-log *CV*
Vasey shin oak	16	6	50	.95*	23	.95*	24	.98*	7	.52*	32
Woollybucket bumelia	10	10	14	.95*	37	.99*	21	.90*	37	.65*	68
Plateau oak	17	12	70	.92*	33	.95*	27	.96*	7	.56*	21
Littleleaf sumac	13	25	10	.93*	44	.97*	29	.92*	40	.42*	106
Agarito	15	22	14	.92*	44	.98*	24	.85*	22	.41*	44
Pricklyash	14	17	55	.92*	38	.93*	39	.90*	16	.57*	34
Sugar hackberry	16	41	22	.89*	60	.89*	62	.72*	29	.60*	34
Texas persimmon	12	25	125	.89*	45	.89*	47	.92*	13	.68*	26
Honey mesquite	13	78	51	.68*	81	.68*	85	.90*	23	.50*	52
Catclaw acacia	14	21	1	.35*	42	.42	42	.62*	623	.35*	818
Elbowbush	13	10	4	.27	29	.45*	26	.58*	20	.24	26
Skunkbush sumac	11	126	1	.02	105	.24	98	.20	128	.07	139

* Significant at the .05 level.

[a] Calculated sample size $= \left(\frac{t_{.05} \times \sqrt{\text{Variance}}}{d}\right)^2$ where d=20% of mean weight.

In the same month, 12 to 17 individual plants of each species with a wide range of volumes were measured to obtain crown volume estimates for the independent variable in the regression equations to be developed. After these measurements were taken, the plants were harvested and leaves and new growth twigs were picked. The picked portions were air-dried and weighed to estimate the weight of edible browse on each individual. This weight estimate served as the dependent variable.

Several regression equations were evaluated for suitability as predictive equations. These equations included linear ($y=a+b_1s$), quadratic ($y=a+b_1x_1+b_1x_1^2$), log-log ($\log y=a+b \log x_1$), and semilog ($\log y=a+bx_1$) functions, where y=weight and $x_1$volume. The coefficients of determinations and coefficient of variability were used to select the equation which best predicted weight per plant. Total edible biomass could be estimated by multiplying weight per plant × plants per ha.

Edible browse for two oak species was estimated at several periods throughout the year by harvesting an additional 15 to 20 plants each period. In this way, new equations to predict weight per plant were developed for each period. The sampling periods corresponded to forage availability: (1) in autumn before frost; (2) in winter before active spring growth; (3) in spring after primary plant growth; and (4) in July after one year of continuous grazing on the study site.

Results and Discussion

Variability among Species

The relation between edible biomass of different browse plants and crown volume was best expressed with either log-log or quadratic regression equations, except for one species, sugar hackberry (*Celtis laevigata* Willd.) (Table 1). Weight of sugar hackberry was predicted equally well with either a linear or quadratic equation. In general, the linear regression equation was a good predictor, but the quadratic and log-log regression had higher coefficients of determination (r^2 or R^2) and lower coefficients of variability. The semi-log (log weight = b_a + b_1x_i) was consistently less satisfactory than any of the other equations.

The way in which predictability (r^2 or R^2) was affected by the quadratic or log-log equations depended upon the species. Estimates for species such as woollybucket bumelia (*Bumelia lanuginosa* (Nutt.) Clark), littleleaf sumac (*Rhus microphylla* Engelm, ex Gray), agarito (*Berberis trifoliolata* (Moric.), and pricklyash (*Zanthoxylum clava-herculis* (Gray) Wats.) were best fitted with quadratic regression equations. These species generally were similar in that their current growth was primarily

Table 2. Coefficients of determination (r^2 or R^2) and coefficients of variability (*CV*) for plateau oak and Vasey shin oak at selected dates based on various regressions of weight on crown volume.

Species	Date	Sample size	Calculated sample size[a]	Mean weight/plant (g)	Linear r^2	Linear *CV*	Quadratic R^2	Quadratic *CV*	Log-log r^2	Log-log *CV*	Semi-log r^2	Semi-log *CV*
Plateau oak	8/75	17	12	70	.92*	33	.95*	27	.96*	7	.56*	21
	11/75	20	41	60	.81	61	.81	63	.92	12	.68	23
	2/76	18	250	20	.62	149	.66	146	.77	54	.79	54
	5/76	18	36	35	.84	57	.98	22	.90	15	.59	30
	7/76	15	7	30	.96	25	.97	22	.93	10	.62	23
Vasey shin oak	8/75	16	6	50	.95	23	.95	24	.96	7	.52	32
	11/75	15	89	25	.65	87	.65	90	.69	29	.57	34
	5/76	17	12	40	.89	34	.90	33	.88	14	.72	22
	7/76	15	7	36	.96	24	.97	24	.85	12	.71	16

* All r^2 or R^2 were significant at the .05 level.

[a] Calculated sample size$= \left(\frac{t_{.05} \times \sqrt{\text{Variance}}}{d}\right)^2$ where d=20% of mean weight.

leaves with little twig elongation. The rate at which they produced this growth seemed to vary with age of the plant (i.e. assuming plants increased in crown volume with increasing age). The new growth on younger plants was greater per unit volume than growth on older plants. Apparently, the increase in weight was rapid at first, then leveled off gradually. Sampling more plants with large crown volumes would have helped clarify this relationship. Unfortunately, there were few of these large plants on the study site.

The log-log regressions accounted for the most variation in Vasey shin oak (*Quercus pungens* var. *vaseyana* (Buckl.) C.H. Muller), plateau oak (Q. virginiana var. *fusiformes (Small) Sarg.), Texas persimmon (Diospyros texana* Scheele), and honey mesquite (*Prosopis glandulosa* Torr.). These plants showed greater variability in weight among the larger (older) plants, possibly due to the lack of uniformity in either growth or the degree to which they were browsed. The r^2 for the linear equation in honey mesquite accounted for only 68% of the variability in edible biomass while the log-log equation accounted for 90%. Scifres et al. (1974) used a linear equation on honey mesquite and reported a high correlation (r=.98). They sampled plants that ranged from seedlings to large trees; whereas, plants with less range in volume were measured in this study. They also sampled more plants with larger volumes, which may have accounted for the higher correlation found in their study.

Those plants that were best fitted with a log-log equation also produced the most edible biomass per plant, with the exception of pricklyash. Thus, plants that produce more edible forage may yield a higher r^2 with a log-log equation. Rittenhouse and Sneva (1977) also found a log-log relationship to be a better predictor of biomass on big sagebrush (*Artemisia tridentata* Nutt.) plants in Oregon. Bentley et al. (1970) used a log-log relationship on several species in California and got good correlations (R=.93 to .97) when the plants were grouped into volume classes. Placing the plants in volume classes might have helped the correlations in this study.

Data from catclaw acacia (*Acacia greggii* (Gray), elbowbush (*Forestiera pubescens* Nutt.), and skunkbush sumac (*Rhus aromatica* Shinners) resulted in poor r^2 regardless of which equation was used (Table 1). Both catclaw acacia and elbowbush had extremely irregular growth forms compared with the other species. The growth of skunkbush sumac was similar to woollybucket bumelia which yielded a linear r^2 of .95. The reason for the poor predictability for these species was unclear. Apparently, edible biomass was either too small for a good relationship or was not well associated with conical volume. Obviously, the proper variables were not selected.

Sample size is an important consideration in any estimate of biomass. The actual sample size for most species, when compared with the calculated sample size, was acceptable except for skunkbush sumac, honey mesquite, and sugar hackberry (Table 1). More plants of these species should have been harvested.

Variability among Sampling Dates

For plateau oak and Vasey shin oak, the r^2 declined as utilization and shedding of leaves reduced forage availability (Table 2). The deciduous Vasey shin oak was not harvested in February since it had little edible foliage. It appears sample size should be increased during seasons of heavy utilization or low availability if the r^2 is to be improved.

The log-log equation provided the best r^2 from late summer through winter, probably due to variability in foliage among individual plants. In late spring and early summer, the quadratic equations best fit the data. Herbivores on this range appear to increase their use of browse from autumn to winter and use it comparatively little during late spring and early summer (Bryant 1977). Thus, sample size should be increased and a log-log equation should be used if availability is determined during periods of heavy browsing.

Conclusion

The equation which should be used to predict weight from crown volume depends upon the plant species and the sampling date. For robust species with ample edible biomass per plant but with inherent variability among plants, the log-log function may yield best results. Other species may require a quadratic function for the best results. Species with irregular growth forms and little available foliage may require special treatment for prediction of weight. Sample size should definitely be increased when plants are being heavily browsed because different degrees of utilization may increase the variability in weight among plants.

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