Estimating Shrub Production from Plant Dimensions

H. GLENN HUGHES, LARRY W. VARNER, AND LYTLE H. BLANKENSHIP

Abstract

Relationships between current season plant production and plant measurements (crown width and volume) were investigated for 4 South Texas shrubs collected during July, 1978. Shrubs investigated were blackbrush *(Acacia rigidula)*, guajillo *(A. berlandieri)*, shrubby blue sage *(Salvia ballotaeflora)*, and kidneywood *(Eysenhardtia texana)*. Regressions of production available to white-tailed deer on both crown width and crown volume yielded coefficients of determination of 25–97%. Log-log and quadratic equations provided better results than linear, logarithmic, or exponential equations. One plant measurement (maximum crown width as an independent variable) produced results comparable to those from crown volume. Range site (sandy loam or gray sandy loam) did not affect plant production:plant measurements relationships, but mechanical treatment (shredding) did. Selecting plants representing the full range of shrub shapes and sizes is critical to the proper use of this method, and treatments which greatly modify plant form will probably require regression equations separate from those for undisturbed vegetation.

Key Words: shrubs, browse production, measurement

Estimating plant production is important in range management as production directly influences the grazing capacity of the range for both native and domestic herbivores. Additionally, knowledge of production is important in evaluating fire fuel loads, revegetation success of mined lands, and plant response to herbicides (Brown 1976, Barker et al. 1977, Scifres et al. 1974). Estimates of shrub production, however, have been more laborious and less reliable than those for herbaceous production. This is caused by (1) required manual separation of current growth from past years' growth, (2) difficulties with shrub density measurements, and (3) variability of plant form, both inherent and as a result of other influences (i.e., animal consumption, mechanical treatment).

Plots, useful in herbaceous production, give variable production results with shrubs and are labor intensive. The weight estimation technique (Pechanec and Pickford 1937), though fast and relatively accurate, requires a subjective determination by the person sampling and results in mental fatigue after several hours of use (Cabral and West 1986). Researchers have examined various plant measurements to determine their usefulness in estimating production. Among these are estimates of crown volume (Lyon 1968, Peek 1970, Rittenhouse and Sneva 1977, Uresk et al. 1977, Bryant and Kothmann 1979). Uresk (1977) noted precision and cost benefits of a double sampling procedure which combined dimension measurements (volume) with harvesting of big sagebrush *(Artemisia tridentata)*. Foresters use plant measurements for biomass estimates (board feet, cubic feet, cords). Often, biomass is used in lieu of the current season's production (Bentley et al. 1970). However, biomass alone is a poor estimate of available forage.

Shrubs dominate the vegetation in South Texas and are important to white-tailed deer *(Odocoileus virginianus)* for food and cover (Steuter and Wright 1980). The objectives of this research were to (1) determine the relationship between plant measurements and plant production for South Texas shrubs, (2) determine which plant measurements most reliably predict current production available to white-tailed deer, and (3) determine the effects of range site and mechanical treatment (shredding) on these relationships.

At the time of the study authors were with the Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station 77843; and Texas Agricultural Experiment Station, 1619 Garner Fld. Rd., Uvalde 78001 respectively. Senior author is currently assistant professor, DuBois Campus, The Pennsylvania State University, Dubois, Pennsylvania 15801.

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Materials and Methods

Samples were collected during July 1978 on the Rio Grande Plain Experimental Ranch located 45 km southwest of Uvalde, Texas. By this time growth had peaked and the effect of animal consumption on production was minimal. The climate of the area is characterized by (1) 270-day growing season, (2) mean annual precipitation of 53.2 cm with highest amounts in spring and fall, (3) hot summers, and (4) usually mild winters.

There are 9 range sites on the Ranch, and the vegetation type varies greatly among sites. The study was conducted on the sandy loam and gray sandy loam range sites where blackbrush *(Acacia rigidula)* and guajillo *(A. berlandieri)* are the codominant woody species. Other important shrubs were kidneywood *(Eysenhardtia texana)*, shrubby blue sage *(Salvia ballotaeflora)*, Texas colubrina *(Colubrina texensis)*, desert-yaupon *(Schaefferia cuneifolia)*, narrowleaf forestieria *(Forestieria angustifolia)*, guayacan *(Porlieria angustifolia)*, twisted acacia *(Acacia tortuosa)*, and spiny hackberry *(Celtis pallida)*.

Four shrub species were selected for production determinations (guajillo, blackbrush, kidneywood, and shrubby blue sage) because these species accounted for 66% of the shrub density on the sandy loam and gray sandy loam range sites as determined by point-center-quarter sampling (Hughes unpublished data). As the average deer can reach to about 125 cm without rearing on its hind legs, this study concentrated on that amount below 125 cm. Transects were established on the 2 range sites with the aid of Soil Conservation Service personnel to include both mechanically treated (shredded) and nonshredded sites. Plants of each species were selected along the transects to include a representative range of plant sizes and shapes.

Each plant was measured to the nearest centimeter for (1) maximum crown width (W1), (2) crown width at right angles to W1 (W2), and (3) height of plant if below 125 cm, or average height of twigs below 125 cm if plant was greater than 125 cm (H1). After measurements were taken, the entire plant was clipped and placed in plastic bags. After an initial drying, current growth from each plant was removed, oven-dried at 60° C for a minimum of 48 hours, and weighed to the nearest 0.1 g.

Total production below 125 cm (leaves, stems, fruit) was analyzed by species. Regression of production below 125 cm (T125) on both widest width (W1) and crown volume (VOL) were conducted using linear ($Y = B_0 + B_1$), logarithmic ($Y = B_0 + B_1 \ln X$), exponential ($\ln Y = \ln B_0 + B_1 X$), log-log ($\ln Y = \ln B_0 + B_1 \ln X$), and quadratic ($Y = B_0 + B_1 X + B_2 X^2$) models. Crown volumes were calculated for each plant by the formula VOL = (pi/4) W1 W2 H1 (Peek 1970).

Multiple regressions with indicator variables (Neter and Wasserman 1974:298) were used to account for the effects of mechanical treatment (shredded or non-shredded) and range site (sandy loam or gray sandy loam) on plant production:crown width relationships. The model used in this analysis was:

$\ln Y = \ln B_0 + B_1 \ln X_1 + B_2 X_2 + B_3 X_3 + B_4 X_4 + B_5 X_5$, where
Y = Total production below 125 cm (T125),
X_1 = Maximum crown width (W1),
X_2 = Range site factor (GSL = 0, SL = 1),
X_3 = Shredding factor (Shredded = 0, nonshredded = 1),
X_4 = $(\ln X_1)(X_2)$ interaction, and
X_5 = $(\ln X_1)(X_3)$ interaction.

Table 1. Regressions of total production below 125 cm (g) on widest crown width (cm) for four South Texas shrubs.

Species/model	n	r^2	slope	y-intcpt.	$S_{y.x}$
Guajillo					
Linear	42	.874	4.289	−199.91	124.35
Log	42	.591	336.84	1224.9	223.75
Log-log	42	.971	2.045	0.012	0.284
Exponential	42	.804	0.019	12.36	0.734
Quadratic	42	.956	−.172/.015	11.909	74.29
Blackbrush					
Linear	22	.806	1.760	− 46.40	46.26
Log	22	.675	111.47	366.25	59.89
Log-log	22	.896	2.057	0.0068	0.543
Exponential	22	.772	0.0276	3.432	0.803
Quadratic	22	.807	1.808/.001	47.79	47.28
Kidneywood					
Linear	27	.871	1.202	− 30.12	19.04
Log	27	.604	58.20	−183.95	33.39
Log-log	27	.944	1.844	0.016	0.318
Exponential	27	.775	0.029	3.560	0.638
Quadratic	27	.905	.521/.003	− 9.61	16.66
Shrubby blue sage					
Linear	26	.921	.920	− 10.943	11.66
Log	26	.816	53.78	−161.29	17.80
Log-log	26	.873	1.604	0.054	0.426
Exponential	26	.659	0.022	6.118	0.699
Quadratic	26	.926	1.164/−.002	17.264	11.46

The log-log model was used because it predicted plant production more precisely than the other models based on R^2 and residual analysis. The effects of range site on the y-intercept and slope were determined by conducting t-tests on the beta-values of X_2 and X_4, respectively. The effects of shredding on the y-intercept and slope were determined by conducting t-tests on the beta-values of X_3 and X_5, respectively.

Results and Discussion

Tables 1 and 2 show the results of regression analyses of T125 on W1 and VOL, respectively. Due to the possible effects of weather and animal consumption on forage production, the equations developed must be used carefully and tested. Coefficients of determination were high for all species, with log-log or quadratic models exhibiting highest r^2 values and nonrandom residuals in all but 1 case. Other researchers have found log-log and quadratic quations useful for a number of species (Bentley et al. 1970, Rittenhouse and Sneva 1976, Bryant and Kothmann 1979). Maximum crown width (W1) predicted oven-dry weight as reliably as crown volume (VOL). Rittenhouse and Sneva (1977) also noted good results in estimating big sagebrush production with 1 variable. Cook (1960) suggested 2 or more plant measurements to a single measurement. The high precision of equations using only W1 as an independent variable probably resulted from width being highly correlated with volume. This is particularly true in shredded areas, where most plants are similar in height.

The log-log model consistently produced high r^2 values and random residuals. The quadratic model, while producing high r^2 values, occasionally resulted in nonrandom residuals. The exponential and logarithmic models proved least reliable in predicting plant production. These models typically had low r^2 values and nonrandom residuals. The linear model produced moderate r^2 values but consistently nonrandom residuals.

The effects of range site and shredding on plant production: crown width relationships are shown in Table 3. Range site had no effect on the regression equations for any of the species measured, but shredding affected either the y-intercept or slope in all species except kidneywood. Coefficients of determination increased and

Table 2. Regressions of total production below 125 cm (g) on crown volume (dm³) for four South Texas shrubs.

Species/model	n	r^2	slope	y-intcpt.	$S_{y.x}$
Guajillo					
Linear	42	.697	1.951	127.77	192.60
Log	42	.246	43.63	−159.85	303.61
Log-log	42	.304	0.230	10.93	1.381
Exponential	42	.323	0.0	65.06	1.326
Quadratic[1]	42	.704	.115/0.0	137.98	192.56
Blackbrush					
Linear	22	.748	0.1186	25.686	52.78
Log	22	.683	36.20	−68.37	59.17
Log-log	22	.945	0.683	1.581	0.394
Exponential	22	.489	0.0015	11.92	1.203
Quadratic	22	.942	.512/.001	2.91	25.90
Kidneywood					
Linear	27	.777	0.107	23.48	25.04
Log	27	.702	22.12	−27.05	28.95
Log-log	27	.891	0.6315	2.825	0.445
Exponential	27	.283	0.0016	14.61	1.139
Quadratic	27	.912	305/−.001	13.99	16.03
Shrubby Blue Sage					
Linear	26	.847	0.071	17.418	16.22
Log	26	.789	18.65	−31.06	19.06
Log-log	26	.845	0.556	2.634	0.472
Exponential	26	.442	0.0015	12.94	0.895
Quadratic	26	.902	.188/−.001	14.145	13.21

[1]Volume of guajillo in m³ because of large plant volumes.

Table 3. Multiple linear regressions evaluating the effects of range site and shredding on plant production:plant measurements relationships.

Species	Variable	Slope	Level of Significance
Guajillo	B_0	−3.873	$p<.01$
n=42	X_1	1.918	$p<.01$
R^2=.974	X_2	0.179	NS
$s_{y.x}$=.282	X_3	−1.063	$p<.05$
	X_4	0.022	NS
	X_5	0.229	$p<.05$
Blackbrush	B_0	−4.025	$p<.01$
n=22	B_0	−4.025	$p<.01$
R^2=.925	X_2	−0.3	NS
$s_{y.x}$=.517	X_3	1.703	NS
	X_4	0.163	NS
	X_5	0.578	$p<.01$
Kidneywood	B_0	−3.813	$p<.01$
n=27	B_0	1.757	$p<.01$
R^2=.944	X_2	−0.134	NS
$s_{y.x}$=.343	X_3	−0.639	NS
	X_4	0.034	NS
	X_5	0.154	NS
Shrubby blue sage	B_0	−4.825	$p<.01$
n=26	B_0	−2.219	$p<.01$
R^2=.950	X_2	10.643	NS
$s_{y.x}$=.294	X_3	1.074	NS
	X_4	−0.165	NS
	X_5	−0.483	$p<.05$

[1]Y = ln T125
B_0 = y-intercept
X_1 = ln W1
X_2 = Range Site Factor (RS)
X_3 = Shredding Factor (SHRD)
X_4 = (ln
X_3 = (ln tion

[2]Significant effect of range site on the equation $Y = B_0 + B_1X_1$ would produce significant slopes for either X_2 or X_4; significant effect of shredding would produce significant slopes for either X_3 or X_5.

standard errors decreased in 3 of the 4 species with the use of the multiple regression as compared to the log-log models in Table 1. The multiple regression did not produce a better model in kidneywood because neither range site or shredding significantly affected the plant production:plant width relationship.

Determination of shrub density is necessary for accurate application of this method. Plant density methods may yield differing results (Beasom and Haucke 1975), so methods must be used which are appropriate for the distribution, size, and character of the shrubs measured.

Plant measurements have potential for predicting shrub production in several South Texas species. The log-log and quadratic models, in particular, work best for the species measured. Obviously more labor intensive than clipping herbaceous vegetation, this technique would work well for areas with up to 3 or 4 major shrub species. Additional species pose logistical and time problems. The key to successful application of this method is selecting plants representing the full spectrum of shrub sizes and shapes. Treatments such as shredding will increase variability, so where shredded and nonshredded areas are sampled, equations must be developed for both shredded and nonshredded areas.

Literature Cited

Barker, R.E., R.E. Ries, and P.E. Nyren. 1977. Forage species establishment and productivity on mined lands. North Dakota Agr. Exp. Sta. Farm Res. 34:8-12.

Beasom, S.L., and H.H. Haucke. 1975. A comparison of four distance sampling techniques in south Texas live oak mottes. J. Range Manage. 28:142-144.

Bentley, J.R., D.W. Seegrist, and D.A. Blakeman. 1970. A technique for sampling low shrub vegetation by crown volume classes. USDA Forest Serv. Res. Note PSW-123.

Brown, J.K. 1976. Estimating shrub biomass from basal stem diameters. Can. J. Forest. Res. 6:153-158.

Bryant, F.C., and M.M. Kothmann. 1979. Variability in predicting edible browse from crown volume. J. Range Manage. 32:144-146.

Cabral, D.R., and N.E. West. 1986. Reference unit-based estimates of winterfat browse weights. J. Range Manage. 39:187-189.

Cook, C.W. 1960. The use of multiple regression and correlation in biological investigations. Ecology 41:556-560.

Lyon, L.J. 1968. Estimating twig production of serviceberry from crown volumes. J. Wildl. Manage. 32:115-119.

Neter, J., and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc., Homewood, Ill.

Pechanec, J.P., and G.D. Pickford. 1937. A weight estimate method for the determination of range and pasture production. J. Amer. Soc. Agron. 29:894-904.

Peek, J.M. 1970. Relation of canopy area and volume to production of three woody species. Ecology 51:1098-1101.

Rittenhouse, L.R., and F.A. Sneva. 1977. A technique for estimating big sagebrush production. J. Range Manage. 27:97-100.

Scifres, C.J., M.M. Kothmann, and G.W. Mathis. 1974. Range site and grazing systems influenced regrowth after spraying honey mesquite. J. Range Manage. 27:97-100.

Steuter, A.A., and H.A. Wright. 1980. White-tailed deer densities and brush cover on the Rio Grande Plain. J. Range Manage. 33:328-331.

Uresk, D.W., R.O. Gilbert, and W.H. Richard. 1977. Sampling big sagebrush for phytomass. J. Range Manage. 30:311-314.