Diameter-Length,—Weight Relations for Blackbrush [*Coleogyne ramosissima*] Branches

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Abstract

Regression was used to relate branch diameter to branch length ($r = 0.85$) and weight ($r^2 = 0.94$) for blackbrush plants in southwestern Utah. These regression equations were subsequently used to estimate blackbrush utilization by domestic goats in a browsing study. The diameter-length equation compared favorably with before-and-after measurements for accuracy and greatly reduced man-hour costs in determining utilization. Estimates of utilization based on the diameter-weight equation were less than estimates based on the before-and-after approach or the diameter-length equation; the diameter-weight equation accounted for leaves and thus provided a more accurate estimate of utilization.

Blackbrush *(Coleogyne ramosissima)* is a shrub occurring in nearly monospecific stands on millions of hectares of rangeland in the southwestern United States. The terminal twigs of blackbrush branches tend to die back for several centimeters from the tip resulting in a spinescent growth form. Death of terminal buds suppresses apical dominance and allows lateral twig development, which has a pronounced effect on compacting the plants. As a result of the compacted, spinescent growth form, the accessibility and palatability of blackbrush forage is low for cattle.

Domestic goats were used to modify the growth form of blackbrush in southwestern Utah (Provenza 1977). Winter goat browsing removed spinescent material from blackbrush plants, which stimulated spring sprouting from basal and axillary buds. Heavily browsed plants produced large quantities of current season's growth, which was more nutritious and digestible than material on unbrowsed plants.

Determining goat utilization of blackbrush was an essential part of this study and required a method which was fast and accurate. Initially, percent utilization was determined by two methods: (1) length measurements of branches before and after goat browsing (Dasmann 1948; Smith and Urness 1962), and (2) a regression approach relating branch diameter to length and weight (Basile and Hutchings 1966; Telfer 1969; Lyon 1970; Ferguson and Marsden 1977). Regression approaches generally relate twig diameter to twig length or weight; this paper, however, presents regression equations relating branch diameter to branch length and weight (a branch included several twigs and each twig consisted of material produced during several growing seasons, Fig. 1).

Methods

The experiment was conducted on Bureau of Land Management administered land in the extreme southwestern corner of Utah near Gunlock. The study area was at an elevation of 1280 m and consisted floristically of blackbrush associated with juniper *(Juniperus osteosperma)*. The soil series of the site was a Pastura Loam with an A-C horizon sequence underlaid by a petrocalcic (caliche) horizon.

The physical design of the experiment consisted of two blocks of 7 ha each. Within each block the heavily stocked pasture was 1 ha,

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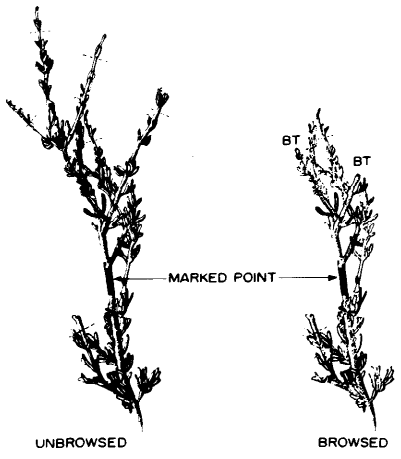

Fig. 1. *Sketch of a blackbrush branch in browsed and unbrowsed condition. Branch material distal to the dashed lines is current season's growth. Caliper measurements were taken at the marked point and at each browsed tip (BT) distal to that point to determine utilization.*

the moderately stocked pasture was 2 ha, and the lightly stocked pasture was 4 ha. Patures were sampled at an intensity of 50 plants per hectare (one branch per plant) to determine utilization.

Percent utilization was quantified by length measurements of marked branches before and after goat browsing. The before measurement was made in December and included approximately 100 cm of browse material that was one-half or more years old; a point on each branch was marked with a dot of red ink and all browse from the marked point to the end of the branch was measured (Fig. 1). The after-browsing measurement was made in March. Utilization was computed as follows:

$$U = [1 - (\frac{A}{B})]\ 100$$

U = percent utilization
where B = length before browsing
A = length after browsing

Equations relating air-dry branch diameter to branch length and oven-dry weight were established by sampling approximately 40 branches in each pasture. Branches selected for measurement corresponded in size and growth form to those browsed by goats. Basal diameters for sample branches ranged from 1 to 5 mm, and approximately 10 branches were sampled in each of four basal diameter classes (1.0–1.9 mm, 2.0–2.9 mm, 3.0–3.9 mm, 4.0–5.0 mm) in each pasture. Basal diameter, as used in this paper, refers to the diameter at the end of the remaining branch from which a sample was removed. The end of the remaining branch was clipped 3 cm below the point from which the sample was taken, and air-dried for 2 weeks before the diameter was measured with calipers to the nearest 0.05 mm; samples were allowed to air-dry before measurement because branches were observed to shrink slightly at the browsing point upon air-drying. Samples were oven-dried for 24 hours at 100° C, weighed to the nearest 0.01 gm, and measured to the nearest 1.0 mm.

Regression equations relating air-dry branch diameter to branch length and oven-dry weight were established for each pasture. Intercepts and slopes of regression lines were compared to determine if the data from all pastures could be pooled.

After goat browsing in March, caliper measurements were made on each branch marked for the before-and-after approach. A measurement was made at the marked point (red ink dot) to predict twig material originally available for goat browsing, and at each browsed tip distal to that point to predict the amount of material browsed by goats (Fig. 1). Utilization was computed as follows:

$$U = \frac{\Sigma PB}{PT}\ (100)$$

U = percent utilization
where PT = prediced branch length or weight before browsing
ΣPB = sum of the predicted browse branch lengths or weights

Results and Discussion

Regression equations providing the best description of the data in the sample were of the general form: (1) natural logarithm length = $B_0 + B_1$ (natural logarithm diameter); (2) natural logarithm weight = $B_0 + B_1$ (natural logarithm diameter). "B_0" and "B_1" are constants for blackbrush. Diameters must be converted to natural logarithmic values before use in these equations. The values obtained are also natural logarithms; the antilog will provide the length or oven-dry weight corresponding to the diameter used in the equation.

A regression line for each of the six pastures was obtained by using indicator varaibles as explained by Neter and Wasserman (1974, p. 297-338). Fitting a model with indicator variables produced the same results as fitting separate equations for each pasture. An advantage of using indicator variables was that one run on the computer yielded all six equations. Also, tests for comparing slopes and intercepts of the regression lines were seen as tests of regression coefficients in a general linear model. For a detailed description of the method applied to blackbrush see Provenza (1977).

Intercept and slope variation among the six pastures for the diameter-length and diameter-weight lines was considered within the bounds of "chance" or error variation; therefore, all six lines were pooled to better estimate the regression parameters. Figures 2 and 3 present the diameter-length and diameter-weight relationships, respectively. The lack of variation in the diameter-length, -weight relationships among pastures with varying blackbrush plant sizes and growth forms suggests that these equations might

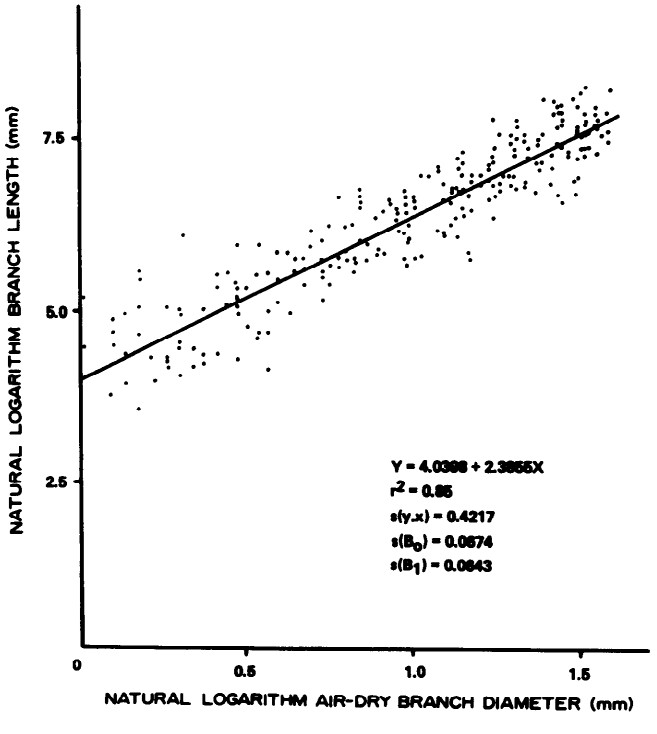

Fig. 2. *Relationship of branch length to air-dry branch diameter for blackbrush.*

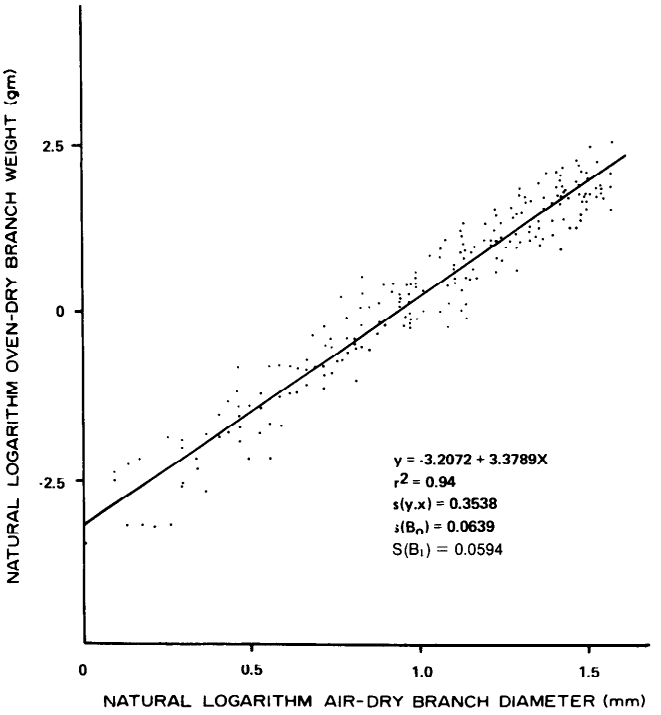

Fig. 3. *Relationship of oven-dry branch weight to air-dry branch diameter for blackbrush.*

apply to other geographical locations where blackbrush occurs. Anyone interested in using these equations should analyze a small sample of blackbrush branches from the four basal diameter classes used in this study to determine whether the equations will provide accurate predictions.

Regression was selected as an alternative method to before-and-after measurements because it reduced man-hour costs. Of interest, however, was how the approaches compared (Table 1). Diameter-length estimates were within 3% of the before-and-after values. The

Table 1. Percent blackbrush utilization (mean ± 95% confidence limits) by goat browsing at three stocking rates.

Pasture[1]	Stocking rate[2]	Before-and-after estimates	Regression estimates Diameter-length	Diameter-weight
1H	649	30 ± 10	31 ± 11	24 ± 10
2H	649	31 ± 12	34 ± 12	26 ± 11
1M	325	13 ± 6	15 ± 6	13 ± 6
2M	325	19 ± 7	21 ± 7	17 ± 6
1L	162	8 ± 3	8 ± 3	6 ± 3
2L	162	4 ± 2	4 ± 2	3 ± 2

[1]H,M, and L designate heavy, moderate, and light stocking intensities, respectively. Numbers denote replicates.
[2]Goat-days per hectare.

Table 2. Comparison of the before-and-after and regression approaches at six levels of utilization (mean ± 95 percent confidence limits). Blackbrush branches were placed in utilization classes based on the before-and-after approach.

Percent utilization	Sample size	Before-and-after estimates	Regression estimates Diameter-length	Diameter-weight
0	546	0	0	0
1-25	46	15 ± 2	22 ± 3	11 ± 2
26-50	27	37 ± 3	43 ± 7	26 ± 6
51-75	21	63 ± 3	70 ± 9	45 ± 9
76-99	34	90 ± 2	89 ± 6	73 ± 8
100	26	100	100	100

diameter-weight utilization estimates were less than the before-and-after or the diameter-length estimates because the browsed twigs comprised a smaller percentage of the branch on a weight basis. The diameter-weight equation also accounted for leaves and thus provided a more accurate estimate of utilization than the before-and-after approach or diameter-length equation which only accounted for branch lengths; goats did not selectively remove blackbrush leaves, but consumed the leaves with the branches when browsing.

Table 2 presents a comparison of the before-and-after and regression approaches at various utilization levels. With equal sample sizes, confidence intervals were larger for regression than for before-and-after estimates; however, regression allowed an increase in sample size. In 1977, 28 man-days were required for before-and-after measures on 700 branches. In subsequent years, only 7 man-days were required for regression measures on 1,400 branches; 4 man-days were needed to select, mark (red ink dot), and measure the branches before goat browsing, while 3 man-days were needed for the after-browsing measures. Increased sample size allowed better estimates of utilization with reduced variability.

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