A Technique for Estimating Big Sagebrush Production

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Highlight: Photosynthetic and woody aerial biomass of big sagebrush was successfully estimated from linear measurements of crown width and area. Combining the above variables with height resulted in higher R^2 values than various crown measurements alone.

It is often desirable to know the total production of the aerial biomass of big sagebrush (*Artemisia tridentata* Nutt.) to study competition among plants, to determine total available browse, to estimate available fuel for control or uncontrolled burning, and so on. Only time-consuming cutting and weighing of entire plants can be used to obtain production estimates. Estimates of photosynthetic biomass are even more laborious.

We studied the relationship between various expressions of linear and area measurements and production of aerial biomass of big sagebrush. In this study measurements were restricted to the subspecies *wyomingensis*.

Methods and Materials

Plants were selected at predetermined points along a line from two different sites about 3.5 km apart on the Squaw Butte Range Station during 2 separate years. The station is about 70 km west of Burns, Oregon, at 1,640 m elevation. Site 1 was on a low terrace with deep soils. Important associated species included little rabbitbrush (*Chrysothamnus viscidiflorus*), basin wildrye (*Elymus condensatus*), bottlebrush squirreltail (*Sitanion hystrix*), Thurber needlegrass (*Stipa thurberiana*), and western groundsel (*Senecio integerrimus*). Site 2 was on an alluvial plain with a moderately deep soil. Important associated species were granitegilla (*Leptodactylon pugens*), bottlebrush squirreltail, Sandberg bluegrass (*Poa sandbergii*), Idaho fescue (*Festuca idahoensis*), and Thurber needlegrass.

On July 14, 1971, and August 5, 1972, whole plants of big sagebrush were cut at ground level following *in situ* measurement of height (H), and two measurements of crown width (W). The first (W_1) was defined as the longest intercept with the second (W_2) taken on a perpendicular line bisecting the W_1 line. Intercept was defined as a vertical projection to a line for photosynthetic plant tissue. Photosynthetic material (biomass) was defined as ephemeral leaves (leaves developing early and shed during periods of stress) and persistent leaves (leaves that overwinter) (Winward 1970). Canopy openings less than 30 cm were considered as continuous intercept. Plant height was measured to the tallest actively growing plant tissue. Measurements were to the nearest 3 cm. Elliptical crown area (A) was determined as

$$\frac{\pi W_1 W_2}{4}$$

Cut plants were placed in large plastic bags. While one end of the bag was left open, the contents were air dried to a constant weight. Photosynthetic biomass was removed from the woody portion, oven dried at 60°C, and expressed as grams on an oven-dry basis. Woody biomass (aerial biomass remaining after removal of leaves) was expressed as grams on an air-dry basis.

Data for 1971 and 1972 were pooled, based on an analysis of co-covariance for homogeneity of regression coefficients ($P>0.10$) and a t test on differences in the Y intercepts ($P>0.10$).

Results

Plants ranged from 34 to 117 cm high and 20 to 119 cm along the W_1 and 19 to 98 cm along the W_2 intercept. Crown surface areas ranged from 58 to 12,872 cm².

When either photosynthetic or woody biomass was plotted against measurements of width or height, the resulting relationship was best represented by the following function:

$$Y = a X^b$$

where Y is a biomass, X is the independent variable and b is the rate of change. For linear approximation the data was transformed to fit an equation of the following form:

$$\log Y = b_0 + b_1 \log X$$

where Y and X are as above and b_0 is log a and $b_1 = b$ (a typical scattergram is given in Fig. 1).

Photosynthetic Biomass

Although $\log (W_1 + W_2)/2$ accounted for the most variability in biomass ($r^2 = 0.90$), it accounted for only 2, 5, and 4 percentage units more than $\log W_1$, $\log A$, and $\log H$, respectively. Log W_2 accounted for only 73% of the variability in biomass (Table 1), and the $s_{y \cdot x}$ was nearly 50% larger than the average $s_{y \cdot x}$ of the other variables mentioned above.

During the research, authors were associate professor, Rangeland Resource Program, Oregon Agricultural Experiment Station, Burns; and range scientist, Agricultural Research Service, U.S. Department of Agriculture, Burns, Oregon 97720. (Oregon Agricultural Experiment Station Technical Paper Number 3996.)

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Table 1. Regression and correlation statistics for various expressions of width and cover vs photosynthetic biomass of Wyoming big sagebrush, oven-dry basis.[1]

	Statistic[2]					
	b_0	b_1	b_2	b_3	$s_{y.x}$	R^2
log W_1	–1.51	1.83			0.216	0.88
log W_1 + log W_2	–1.53	1.47	0.413		0.208	0.89
log W_1 + log H	–2.46	1.05	1.28		0.125	0.96
log W_1 + log W_2 + log H	–2.44	0.786	0.320	1.24	0.114	0.97
log W_2	0.900	1.62			0.316	0.73
log W_2 + log H	–2.52	0.738	1.67		0.157	0.94
log (W_1 + W_2)/2	–1.47	1.88			0.195	0.90
log (W_1 + W_2)/2 + log H	–2.36	1.13	1.19		0.114	0.97
log A	–1.86	0.929	1.19		0.234	0.85
log A + log H	–2.71	0.507	1.36		0.132	0.96
log H	–2.68	2.39			0.227	0.86

[1] W_1 and W_2 are plant intercept of width and bisecting width, respectively. A is elliptical area, and H is height

[2] b_0 is log a, and b_i corresponds to its respective variable.

Combining log W_2 with log W_1 resulted in an improvement in the R^2 value of only 1%. However, combining log H with individual variables resulted in an improvement in the R^2 values, i.e., 0.88 to 0.96, 0.73 to 0.94, 0.90 to 0.97, and 0.85 to 0.96 for log W_1, log W_2, log (W_1 + W_2)/2 and log A, respectively. Adding log H to log W_1 plus log W_2, changed the R^2 only 1% over log W_1 plus log H. In all cases adding log H reduced the standard error of the estimate to about 50–60% of the $s_{y.x}$ of the individual variables.

Woody Biomass

Combining log W_1, log (W_1 + W_2)/2, or log A with log H increased R^2 values from 0.86 to 0.95, 0.88 to 0.95, and 0.85 to 0.96 respectively. The coefficient of determination of log W_2 increased from 0.72 to 0.93 when log H was added (Table 2).

Table 2. Regression and correlation statistics for various expressions of width and cover vs woody biomass of Wyoming big sagebrush, air dry basis.[1]

	Statistic[2]					
Item	b_0	b_1	b_2	b_3	$s_{y.x}$	R^2
log W_1	−2.06	2.55			0.326	0.86
log W_1 + W_2	−2.08	2.03	0.585		0.317	0.87
log W_1 + H	−3.43	1.40	1.86		0.204	0.95
log W + log W_2 + log H	−3.41	1.03	0.450	1.81	0.192	0.95
log W_2	−1.21	2.25			0.456	0.72
log W_2 + log H	−3.52	0.999	2.37		0.237	0.93
log (W_1 + W_2)/2	−1.99	2.61			0.300	0.88
log (W_1 + W_2)/2 +log H	−3.30	1.51	1.74		0.190	0.95
log A	−2.58	1.30			0.330	0.85
log A + log H	−3.78	1.89	0.717		0.191	0.95
log H	−3.73	3.35			0.324	0.86

[1] W_1 and W_2 are plant intercept of width and bisecting width, respectively, A is elliptical area, and H is height.

[2] b_0 is log a, and b_i corresponds to its respective variable.

Discussion

Even though the data in this study are presented in terms of a static model, the reader should be aware of the fact that the sagebrush plant is dynamic in its physiological response to climatic variables. In this study, plants were harvested before ephemeral leaf-drop. Both 1971 and 1972 were near-average years, i.e., 105 and 94% of the long-term average crop-year precipitation.

In order to apply the relationships presented above, the mean

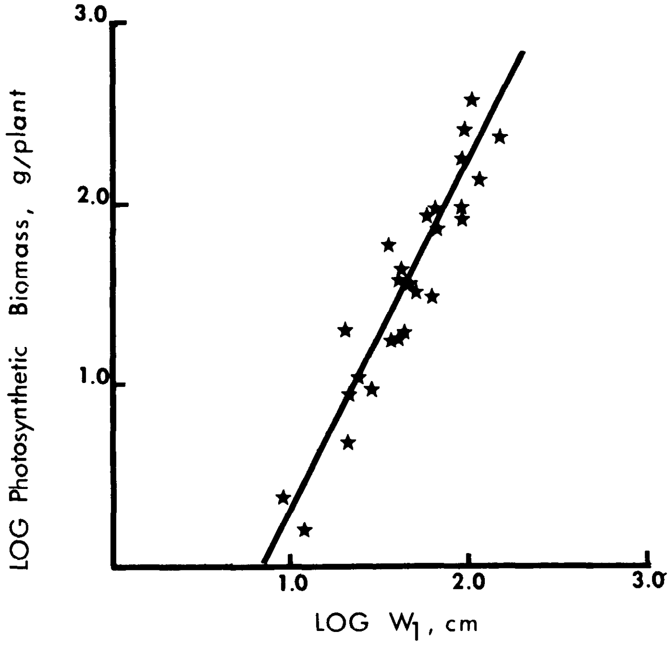

Fig. 1. *Relationship between longest width (W_1), cm, and photosynthetic biomass of Wyoming big sagebrush, g/plant, on a log-log scale.*

width, height, or area of individual plants within a population and density of plants per unit area must be determined. Considering ease in measurement and the magnitude of the $s_{y.x}$ and r^2 or R^2, either photosynthetic or woody biomass per plant would be estimated from mean width (W_1) and height (Tables 1, 2). In this case, all but 4 to 5% in the variability of biomass per plant could be accounted for by simple linear measurements. Use of linear measurements is justified by the fact that no relationship was found between biomass, expressed as log g/m^2, and log width$_1$ (P>0.10). Examples of predicted photosynthetic and woody biomass from width$_1$ and height with their respective 95% confidence intervals are given in Table 3. By combining average biomass per plant (B) with density per unit area (D), i.e., BD, an estimate of photosynthetic or woody biomass per unit area could be made. We assume, of course, that sufficient plants were measured to give an acceptable degree of precision of estimates of the independent variable and density.

The data also imply that biomass of Wyoming big sagebrush

Table 3. Predicted biomass of Wyoming big sagebrush (g/plant) with the lower and upper limits of the 95% confidence intervals, using width, and height (cm).

		Biomass					
		Photosynthetic			Woody		
Width	Height	Mean	Lower	Upper	Mean	Lower	Upper
10	15	1.2	1.1	1.7	1.4	0.0	2.4
	20	1.8	1.3	2.4	2.4	1.5	3.9
20	30	6.2	5.1	7.5	13.6	10.0	18.6
	35	7.5	6.2	9.0	18.2	19.9	24.5
	40	8.9	7.4	10.7	23.2	17.1	31.7
40	40	18.4	15.7	21.6	61.3	47.2	79.5
	60	30.8	27.2	34.9	130.0	106.0	160.0
	80	44.5	36.8	53.8	222.0	163.0	303.0
80	70	77.4	66.4	90.5	404.0	356.0	589.0
	90	107.0	92.2	124.0	730.0	574.0	927.0
	110	138.0	115.0	165.0	1,059.0	771.0	1,418.0
120	80	141.0	113.0	174.0	1,034.0	728.0	1,470.0
	100	187.0	154.0	226.0	1,566.0	1,147.0	2,138.0

per unit area could be estimated from percentage crown cover, provided the rate of change of log percentage crown cover and log biomass per unit area was zero. Such a calculation was not possible using the data collected in this study, since the calculations involved confounded the errors associated with the dependent and independent variables.

In this study the functional relationship of width, height, and biomass was independent of site and years and agrees with Winward (1970). He reported a close relationship of stem diameter with age of Wyoming big sagebrush in Idaho, probably because of the characteristic growth of the subspecies *wyomingensis*. Lyon (1968) found considerable differences in the relationship between crown volume of serviceberry (*Amelanchier alnifolia*) and current annual twig production on various sites. We would, however, expect annual production to be more site-sensitive than total biomass. Bently, Seagrist, and Blakeman (1970) found no differences in the relationship between crown volume classes and dry weight in several stands of different volume classes of manzanita (*Arctostaphylos patula*), Chinkapin (*Castanopsis sempervirons*), snowbrush (*Ceanothus velutinus*), and bitterberry (*Prunus emarginata*).

Bentley et al. (1970) expressed their data on a log-log scale and reported R^2 values of 0.86 to 0.94 between the dependent and independent variables. This result supports the use of the exponential form used in this study.

Literature Cited

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THESIS: THE UNIVERSITY OF ARIZONA

Characterization of Range Sites in the Empire Valley, Arizona, by J. A. de Araujo Filho, PhD, Range Sciences. 1975.

This research deals with the characterization of range sites in the Empire Valley study area, 40 miles southeast of Tucson, Ariz. Black-and-white aerial photographs were used in the reconnaissance, stratification, and selection of 304 stands evaluated during 1973 and 1974. Field data collected by ocular reconnaissance from each stand included a list of species, dominance, and composition ratings of individual species in herbaceous, shrub, and tree layers, percentage cover of the vegetation layers, cobbles and gravel, soil series, topographical position, slope percent and aspect, and present grazing intensity.

Stands were classified into three major categories based on topographical position and limyness of the soil: bottomlands, nonlimy uplands, and limy uplands. Specific plant communities and gravel cover on the soil surface were used to separate tentative sites on the bottomlands. Solar radiation at the soil surface as affected by slope angle and aspect, slope percent, and cobble cover were used to separate the tentative sites of both the nonlimy and the limy uplands. Multiple regression analyses between the abiotic site factors, as independent site variables, and individual plant species importance values, as dependent variables, were used to test the influence of the abiotic environmental factors on the occurrence of plant species in the study area. Cluster analyses based on coefficients of similarity among stands were conducted, and groups of stands of similar vegetation composition were identified. Correlations among plant species were tested and possible range site condition and site potential interactions were discussed.

Four tentative sites identified on the bottomlands were justified. Sites 1 and 4 were separated on the basis of specific plant communities, dominated by *Hilaria mutica* and *Sporobolus wrightii* and/or tree-size *Prosopis juliflora*, respectively. Sites 2 and 3, separated on the basis of gravel cover, reflect the differences between Comoro and Pima soil series in terms of vegetation cover. The vegetation groups associated with these latter two sites were greatly influenced by range condition.

The 10 tentative sites of the nonlimy uplands were regrouped into seven range sites. Site 6, representing the steep south slopes, was justified in terms of characteristic plant species, radiation, and slope. Tentative sites 8 and 11, initially separated in terms of the difference in cobble content, were combined into a single range site because the effects of the differences in range condition obscured the differences caused by the small cobble cover percent. Tentative site 10, representing the flat uplands with fine textured soils, was justified as a range site and supported a specific plant community dominated by *Hilaria mutica*. Tentative sites 13 and 15, the gentle and moderate slopes of the 600–700 langleys/day radiation class did not present sufficient plant community differences to justify a separation into two distinct range sites. Site 17, representing the steep slopes of the 600–700 langleys/day radiation class was separated as a distinct range site based on differences in slope and plant community. Two distinct range sites were identified in the low radiation classes in terms of characteristic plant communities. Sites 19 and 22, radiation classes 500–600 and 400–500 langleys/day, respectively, were combined as one site. Site 24, radiation class 300–400 langleys/day, was justified as a distinct range site separated from other north slopes because of steep slope, low herbaceous cover, and presence or absence of specific species.

No attempt was made to separate sites on the limy uplands, due to the inadequate number of samples per tentative sites. However, trends indicate a pattern in the number and characteristics of range sites similar to those of the nonlimy uplands.