Ecology and Population Biology Session

Estimating Aboveground Biomass of Mariola (*Parthenium incanum*) from Plant Dimensions

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Abstract: The distribution and abundance of plant biomass in space and time are important properties of rangeland ecosystem. Land managers and researchers require reliable shrub weight estimates to evaluate site productivity, food abundance, treatment effects, and stocking rates. Rapid, nondestructive methods are needed to estimate shrub biomass in semi-arid ecosystems. Shrub height and crown diameter are useful non-destructive measures of shrub size. Mariola (*Parthenium incanum*) is an important shrub that is widely distributed in the Chihuahuan and Sonoran deserts. Mariola is found from the southwest United States to the central part of Mexico. Regression analyses were used to examine the relationships between aboveground biomass and four plant measurements (shrub height, longest canopy width, shortest canopy width, and crown volume) from 45 plants. All variables were related to aerial biomass; R values varied from 0.73 to 0.98. Regression equations developed for mariola compared favorably to equations in similar species in desert environments, suggesting that results might be applicable to other desert regions for rapid and accurate estimation of shrub biomass.

Introduction

The Chihuahuan desert is the largest of the three creosote-bush-dominated deserts in North America. The Chihuahuan desert covers 450,000 to 629,000 km^2 (Henrickson and Straw 1976; Morafka 1977; Dinerstein and others 2000) in eastern Chihuahua, western Coahuila, San Luis, Potosi, southern Nuevo Leon, northeast Zacatecas, eastern Durango, southwest Texas, and southern New Mexico, as well as smaller but equally distinctive areas in southeast Arizona and northeast Sonora (Brown 1982). Chihuahuan desert grasslands contain a varied flora of herbaceous, suffrutescent, and woody species. Vegetation pattern is spatially diverse across the landscape and is influenced by highly variable patterns of precipitation and subtle changes in edaphic factors as well as natural and anthropogenic disturbance regimes (Buffington and Herbel 1965). Creosotebush, (*Larrea tridentata*), is a prominent element of the Chihuahuan Desert, often covering large areas. Other common shrubs include catclaw (*Mimosa biuncifera*), mesquite (*Prosopis glandulosa*), mariola (*Parthenium incanum*), fourwing saltbush (*Atriplex canescens*), tarbush (*Flourensia cernua*), javelinabush (*Condalia ericoides*), goldeneye (*Viguiera cordifolia*), and ocotillo (*Fouquieria splendens*). Among these shrubs, fourwing saltbush (*Atriplex canescens*) and mariola (*Parthenium incanum)* are important components of the diet of grazing animals.

Maynez and others (1984) evaluated the nutritional value of mariola by collecting samples during 1 year in a monthly period. They found the highest crude protein (CP) values during September (20.3 percent) and April (18.3 percent). The lowest CP contents were measured during the months of October (11.7 percent), November (12.6 percent), and January (13.6 percent). The highest percentages of mariola in vitro organic matter digestibility (IVOMD) were determined during the months of September and April – 65.5 and 63.5 percent, respectively. In contrast, the lowest IVOMD values were found in November with an average of 54.1 percent.

Mariola is one of the most important components of the diet of grazing animals on a desert shrublands. Marquez and others (1984) used esophageal fistulated steers to determine dietary botanical composition. The most important plants were mariola buddleja (*Buddleja scordiodes*) and oreganillo (*Aloysia wrightii*). Mariola constituted about 31 percent of their diet for grazing steers. Villalobos and others (1984) working in the same vegetation type estimated that on

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average, 18 percent the diet with esophageal goats was made up of mariola.

The distribution and abundance of plant biomass in space and time are important properties of rangeland ecosystem. Researchers and natural resources managers require reliable estimates of shrub weights to assess site productivity, food abundance, treatment effects, and stocking rates. The accurate measurement of vegetative biomass by traditional clipping and weighing is a time-consuming and labor-intensive process. As a result, indirect methods are needed to rapidly determine shrub aerial biomass. Considerable research has gone into estimating the biomass of individual shrub species (Tucker 1980; Murray and Jacobson 1982; Frandsen 1983; Navar and others, 2002). However, established techniques, such as harvesting, are slow and expensive. Shrub height and crown diameter are useful non-destructive measures of shrub growth, but precise direct estimates of yields of aerial biomass require destructive methods that are unsatisfactory in studies on perennial shrubs.

Uresk and others (1977) estimated that clipping big sagebrush (*Artemisia tridentata*) phytomass was 120 times more expensive than using dimension analysis. Using the weight estimate technique (Pechanec and Pickford 1937) requires a considerable training and clipping to check estimates. A technique that is rapid, relatively accurate, and requires little training is desirable. Tufts (1919) found a high correlation between trunk circumference and weight of the top of fruit trees. Since this early beginning, many others including Kittredge (1944), Attiwill (1962), Baskerville (1965), and Brown (1978) have used combinations of trunk diameter, total height, live crown length, ratios of live crown length to total height, and crown widths to estimate tree biomass. In most cases, very useful predictive relationships were developed from these simple measurements. Similarly, biomass estimates of various shrub species and plant fractions have been developed using stem diameters (Telfer 1969; Brown 1976), crown diameter axes (Rittenhouse and Sneva 1977), crown volume (Chew and Chew 1965; Lyon 1968; Mack 1971; Burk and Dick-Peddie 1973; Ludwig and others 1975; Rittenhouse and Sneva 1977; Wakimoto and Menke 1978), crown cover (Ludwig and others 1975), and height x circumference (Harniss and Murray 1976) as independent variables.

A large number of variables can be used to predict biomass. However, variables that express the size of the crown or the volume appear to be most useful. The objective of this study was to examine the relationships between aboveground biomass and four plant measurements (shrub height, longest canopy width, shortest canopy width, and crown volume) recorded in the field.

Materials and Methods

This study was conducted on a private ranch 50 km east of Chihuahua city (28° 46' N, 65°50' W) at elevation of 1,150 m. The climate of the region is semi-arid and warm. The average annual precipitation is 250 mm, with about 65 percent occurring between July and September. The vegetation is characterized by perennial, drought resistant woody species adapted to conserve water in drought periods; perennial grasses; and various types of annual species. Dominant shrubs are creosotebush, mariola, tarbush mesquite, saltbush, and yucca (*Yucca* spp.). The study site received moderate continuous grazing all year by domestic livestock.

Four morphological variables were used to estimate aboveground biomass: plant height, longest canopy width, shortest canopy width, and crown volume. Mariola volume was computed as if the plant was the upper half of a spheroid in shape with the formula: canopy volume = π (4/3) a^2 b, where a is the average of the longest and shortest radii, and b is plant height (Ludwig and others 1975). Plant morphological measurements were recorded in the field on 45 randomly selected plants in December. A single estimate of biomass during December was considered an adequate basis to estimate shrub production because current year shoots and leaves remain attached to the plant and are easily identifiable. We did not consider diameter increases of branches but only their elongation; thus, our data may have a bias towards underestimation.

After recording morphological measurements, shrubs were clipped at ground level with all aboveground parts including branches, stems, and leaves collected. All plants were dried at 60°C to a constant mass and weighed to the nearest 0.01g. Plants chosen for this analysis represent the range of sizes encountered in the region based on experience with field work that occurred in conjunction with this study involving botanical composition of the diet of grazing animals at the same site. All plants collected were judged to be in good condition at the time of harvest and were collected from similar range sites.

Regression analyses were used to examine the relationships between aboveground biomass and four field measurements shrub height, longest canopy width, shortest canopy width, and crown volume from 45 plants.

Results and Discussion

The range in the height, longest canopy width, shortest canopy width, and crown volume of the shrubs was 17 to 77.0 cm (mean 42.82 cm, standard deviation [SD] 16.06 cm); 18 to 132 cm (mean 61.29, SD 29.48 cm); 16 to 124 cm (mean 52.51 cm, SD 25.41 cm); and volume, 0.3845 to 0.9939 cm^3, respectively,. Time spent clipping and harvesting each plant, averaged 20 to 30 minutes. In contrast, taking all the measurements averaged 4 to 6 minutes/plant.

All independent variables were highly correlated with shrub biomass. In general, the relationship among the variables, height, longest canopy width, and shortest canopy width, showed an exponential relationship. In contrast, crown volume indicated a linear relationship. The linear regression modeling results showed that different plant attributes predict plant biomass with a high coefficient of correlation (table 1).

Analyzing each independent variable individually showed that plant volume had the highest correlation with biomass (r = 0.97). Rittenhouse and Sneva (1976) and Bryan and

Table 1. Coefficients of determination for predicting total aboveground biomass of mariola (*Parthenium incanum* (n = 45).

Variables		Coefficients		Statistics			
Dependent	Independent	β_0	β_1	P > F	r^2	$S_{x.y}$	n
Biomass	Height	-412.1	14.23	0.00	.730	0.31	45
Biomass	Longest canopy width	-317.7	8.406	0.00	.859	0.51	45
Biomass	Shortest canopy width	-313.5	9.73	0.00	.855	0.60	45
Biomass	Volume	-13.55	.0012	0.00	.965	0.87	45

Kothmann (1979) found similar results between aboveground biomass and volume. Longest canopy width (r = 0.86), shortest canopy width (r = 0.74), and height (r = 0.73) also were individually significantly related to biomass. Other studies on desert shrubs have demonstrated strong relationship between biomass and morphological measurements. Felker and others (1982) showed that the dry matter weight of *Prosopis* was highly correlated (r^2 = 0. 99) with stem diameter. Sosa and Perez (1983) and Sosa and Baez (1985) mentioned that height was the best predictor of biomass for *Mimosa biuncifera* and *Menodora scabra*. However, height had the lowest correlation with the biomass in the current study. This may be related to differences among species in individual growth form and in response to site resources. Rittenhouse and Sneva (1977) also noted useful results in estimating big sagebrush biomass with one variable. Longest canopy width was successfully used to estimate biomass of mariola. Therefore, using at least one these variables, biomass can be estimated. However, Cook (1960) suggested using two or more plant measurements to a single measurement.

Although the statistical analysis in this study indicates strong relationships between plant attributes and biomass, caution should be used in estimating mariola biomass for seasons other than the season used in this study. The time of year when biomass prediction equations were developed for mariola can influence the magnitude of the equations parameters. Plant measurements have potential for predicting mariola production in the Chihuahuan and the Sonoran desert, mainly due to mariola definite growing pattern. Using prediction equations to estimate mariola biomass saves time and is not a destructive procedure.

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