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ESTIMATING BIOMASS IN COASTAL *BACCHARIS PILULARIS* DOMINATED PLANT COMMUNITIES

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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

ESTIMATING BIOMASS IN COASTAL *BACCHARIS PILULARIS* DOMINATED SHRUB TYPES

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ABSTRACT

Communities dominated by *Baccharis pilularis* are expanding in coastal California altering fuel load on a landscape scale, yet there is no standard method for estimating biomass in this vegetation type. In an attempt to develop a non-destructive field method for estimating biomass in *Baccharis* dominated communities, we compared three indirect measures including crown canopy height, basal stem diameter, and leaf area index (LAI) estimated using hemispherical photography. Data were collected on a total of 90 one meter^2 randomly selected plots in Point Reyes National Seashore and Golden Gate National Recreation Area. Linear regression analysis was used to determine the effectiveness of each predictor. The best single predictor of biomass was crown canopy height with an adjusted R^2 of 0.46 for both sites combined. The linear regression equation developed for biomass versus height predicted 3930 grams per meter in height ± 430 grams for each meter^2 on these sites. Basal stem diameter was determined to be a weak predictor in this vegetation type. Estimated LAI had no predictive value. Multiple linear regression with biomass versus height and basal area was also tested resulting in a slightly stronger model with an adjusted R^2 of 0.48. Because of its predictive value, and ease of implementation, we suggest the use of crown canopy height as the most efficient biomass predictor in this vegetation type.

Keywords: *Baccharis pilularis*, Coyote brush, biomass, fuel estimation, fuel measurement

INTRODUCTION

Coastal shrublands dominated by *Baccharis pilularis* (coyote brush) are common in Northern California. This vegetation type is expanding into areas previously dominated by grasses altering biomass accumulation and potential fire hazard (Russell and McBride 2003). The precise effect of this conversion is difficult to determine, as there is currently no standard method for estimating biomass in *Baccharis* dominated communities. The objective of this study was to compare three non-destructive methods of estimating biomass in the coastal *Baccharis* shrub type with the goal of discovering a practical field predictor.

Fire is an important factor in the development of *Baccharis* communities. Fire is historically prevalent in this vegetation type and it may serve a role in the regeneration of the dominant species (Schwilk 2002). In addition, the frequency and intensity of fire may be a determining factor it the distribution of *Baccharis* on the landscape. The absence of fire in combination to changes in grazing patterns may be a significant factor in the replacement of grasslands with *Baccharis* shrublands (Russell and McBride 2003, Williams et al. 1987, Elliot and Wehausen 1974, McBride and Heady 1968).

Baccharis pilularis is a perennial evergreen shrub common to the coastal areas of California. It is a rapidly growing species especially early in its life cycle. Individual plants may live as long as 100 years, surviving by a process of stem replacement

(McBride and Barnhart 2002). On productive sites *Baccharis* often exceeds two meters in height creating a significant fuel load.

Comparisons of direct and indirect methods to assess biomass have been studied in forested vegetation (Reinhardt et. al 2000). However, there are no accepted standardized methods for assessing fuels in coastal shrub vegetation types. In addition, the currently accepted fuel models do not adequately address *Baccharis* and other coastal shrub vegetation (Keane et al. 1994, Anderson, 1982).

Review of previous work on biomass estimation led to the selection of three potential indirect methods for estimating fuel load in the *Baccharis* shrub type. These included height measurement (Russell and McBride 2003), basal stem diameter measurement (Brown 1976), and the estimation of leaf area index (LAI) using a portable hemispheric photography unit, the LAI-2000. Similar tests using LAI have been conducted in forested communities with favorable results (Chen et al. 1991).

We selected as our study areas Golden Gate National Recreation Area and Point Reyes National Seashore. The two parks are similar in their vegetation communities, and in their wildland-urban interface issues. These sites represent only a small portion of the area being affected by the conversion of grasslands to shrub-dominated communities, and *Baccharis* represents only one of many shrub types in the region. The need for quantifying biomass in shrub vegetation extends into many different vegetation types. The methods used to test predictors in this study will be applicable in all of these areas, but the best predictors will need to be determined separately for each vegetation type.

METHODS

Study Sites

This study was conducted in Point Reyes National Seashore and Golden Gate National Recreation Area in California. These study areas were divided into two distinct ecological types of *Baccharis*, early-successional *Baccharis* dominated scrub at Point Reyes National Seashore, and mature *Baccharis* dominated coastal sage scrub at the Marin Headlands at Golden Gate National Recreation Area. Forty-five plots were randomly sampled in each type for a total of 90 plots across the entire study area. The data were analyzed for differences both between and within these ecological types.

Sampling Methods

Sample points were randomly located using the Arc View GIS Alaska Tool Pak within polygons designated as *Baccharis* in the Point Reyes National Seashore digital vegetation map (Shirokauer 2001). Only plots with 70-percent *Baccharis* canopy cover were accepted. If the plot did not meet the criteria, a new direction was chosen at a random azimuth. The plot was then located 10-meters in that direction. . If the plot still did not meet the criteria, 90-degrees was added to the first random azimuth. The procedure was repeated at 180-degrees and 270-degrees until an acceptable plot was located. All plots were located at least 10-meters away from any trail or road.

LAI using hemispherical photography

The LAI- 2000 (Li-Cor, Inc. Lincoln NB), designed for measuring leaf area index for multiple growth forms (grass, shrubs, trees), has been used primarily to estimate biomass in forest systems (Reinhardt et al. 2000). Measurements made at each of the cardinal directions above and below the canopy were used to determine canopy light interception, from which LAI (leaf area index) was computed using a model of radiative transfer in vegetative canopies (Li-Cor 1992). The standard protocol for shrubs given in the Li-Cor operators' manual was employed, using a 30-degree mask on the sensor to block the operator from reflection on the lens. The LAI estimation was compared with linear regression to biomass results from subsequent clipping and weighing procedures.

Basal stem diameters

Estimation of live fuel biomass from stem diameter measurement using the method described by Brown (1976) was conducted on all sample points. The sample area for this procedure was a one square meter plot centered on the sample point. The diameter of all woody stems were measured 5-centimeters above the ground to the nearest millimeter. Diameters were converted to basal area and summed for each plot. Basal area estimation was compared with linear regression to biomass results from subsequent clipping and weighing procedures.

Canopy height

Canopy height was estimated at each sample point using metered pole fixed to the four corners of a 1-meter^2 PVC plot frame. The base of the plot frame was placed on the ground with one corner at the sample point and the arms of the plot projecting in the North and East directions. The mean height of the plot was determined by averaging the height at the four stakes. Height was measured to the nearest 0.01-centimeter. Canopy height estimation was compared with linear regression to biomass results from subsequent clipping and weighing procedures.

Biomass

All plant material at each sample point within the 1-meter^2 was removed mechanically then separated into 0.5-meter vertical layers on site. The separated material was then placed in a drying oven at 52-degrees C. Drying times were determined by taking progressive weight measurements until weights remained unchanged for 3 hours. Biomass was measured to the nearest 0.1-gram.

Statistical Analysis

Linear regression models were used to assess the effectiveness of LAI, basal stem diameters, and canopy height in predicting biomass. Normal distribution of residuals was found for variables included in the models. If two or more variables were found to be significantly predictive of biomass, then multiple linear regression models based on these multiple predictors were assessed for any further improvement in predicting biomass. A significance level of 0.05 was used to evaluate the significance of all regression relationships, and adjusted R^2 was used to compare the predictive value between regression models.

RESULTS

Comparison of shrub biomass with three variables indicated a significant linear relationship between crown canopy height and biomass. A weaker but significant linear relationship was also found between basal area and biomass. No linear relationship was found between measured biomass and estimated LAI. Significant differences were found between the two study areas in terms of basal area, height, and biomass, but the relationships between the dependent and independent variables were similar on both study areas.

<u>Linear regression analysis between height and biomass</u>

Linear regression analysis was performed between biomass and height. Several transformations of the biomass variable were tested to determine if the model could be improved including, square root, cubic root, and natural log. The residual fit was best with the untransformed variable, and the R^2 changed very little between transformed models, so that none of the transformations were employed in the following analysis. A significant linear relationship was found between biomass (grams) and crown canopy height, (adjusted R^2= 0.46, P< 0.01, figure 1). The linear regression equation, biomass (grams) = 238.48 + 3701.36 height (meters), describes a biomass averaging 238.48 grams (standard error = 43.28 grams) for plots with stakes measuring zero crown canopy height and increasing by 3701.36 grams (standard error = 43.28 grams) per meter increase in height, for each square meter plot.

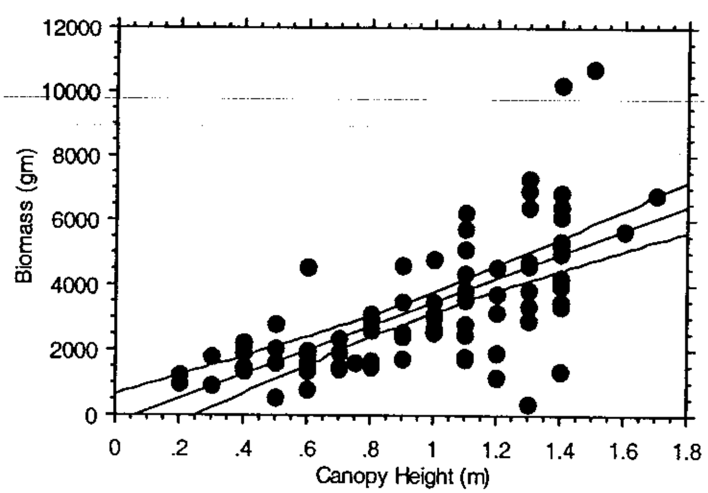

Figure 1. Linear regression, with 95% confidence bands, (adjusted R^2= 0.46), between the crown canopy height of the shrub layer and the dry weight removed from ninety 1-meter^2 plots within *Baccharis* shrubland in the Point Reyes National Seashore and Golden Gate National Recreation Area, California.

Linear regression analyses were also performed for each study site individually. Significant relationships were found between biomass and height on both sites. The linear regression for Golden Gate National Recreation Area was biomass (grams) = 303.20 + 2339.01 height (meters), with an adjusted $R^2 = 0.33$ and $P< 0.01$. The linear regression equation for Point Reyes National Seashore was biomass (grams) = 950.23 + 4542.73 height (meters) with an adjusted $R^2 = 0.48$ and $P< 0.01$.

<u>Linear regression analysis between basal area and biomass</u>

A linear regression analysis was performed between biomass and basal area (centimeters^2). A significant, but weak, linear relationship was found (adjusted $R^2 = 0.17$, $P< 0.01$). Linear regression analyses were also performed for each study site individually. No significant linear relationship was found between biomass and basal area on Golden Gate National Recreation Area. A significant linear relationship was found between biomass and basal area for Point Reyes National Seashore. The regression equation for Point Reyes National Seashore was biomass (grams) = 51.68 + 0.02 basal area (centimeters^2) with an adjusted $R^2 = 0.53$ and $P= 0.01$.

<u>Linear regression analysis between leaf area index (LAI) and biomass</u>

A linear regression analysis was performed for biomass versus estimated LAI. No significant linear relationship was found between estimated LAI and biomass. Linear regression analyses were also performed for each study site individually. No significant linear relationship was found for either site.

<u>Multiple regression analysis between biomass and two independent variables</u>

A multiple regression analysis was conducted with biomass versus height and basal area. A significant relationship was found (adjusted $R^2 = 0.48$, $P< 0.01$). Multiple regression analyses were also performed for each study site individually. Significant linear relationships were found between biomass versus height and basal area on both study sites. The regression for Golden Gate National Recreation Area resulted in an adjusted $R^2 = 0.32$ and $P< 0.01$. The regression statistics for Point Reyes National Seashore were adjusted $R^2 = 0.57$ and $P< 0.01$. A simple linear regression model with biomass (grams) versus a unified variable, height (meters) x basal area (centimeters^2), was also tested. This model indicated a significant linear relationship, but was a relatively weak predictor (adjusted $R^2 = 0.27$, $P< 0.01$).

DISCUSSION

The objective of this study was to compare three nondestructive methods for estimating biomass in coastal *Baccharis* shrublands, and to develop a predictive model that can be used in the field for fuel characterization. The three methods tested included crown canopy height measurement, basal area measurement, and leaf area index (LAI) estimation through hemispherical photography. Of these three methods, crown height was the best predictor of measured biomass. Basal area was less accurate due to the variation in the basal area to biomass ratio between plots, and between sites. The final estimator tested, leaf area index as estimated using the LAI-2000 was not valuable as a predictor.

The linear regression analysis between measured biomass and crown canopy height yielded a useful predictive model. This method was also the most efficient in terms of time and ease of measurement. Variation occurred in the height to biomass ratio between the plots sampled on the younger stands in Point Reyes National Seashore compared to the older stands in Golden Gate National Recreation Area, but this variation was much less pronounced than it was for basal stem diameter.

The linear regression analysis between measured biomass and basal area did not yield a useful predictive model. This measure did not predict biomass as well as crown height in part because shrubs that were measured for height and biomass on a specific plot were sometimes rooted outside of that same plot. Using larger plots would have limited this problem, though not eliminated it. The linear regression model for Point Reyes National Seashore was stronger than that for Golden Gate National Recreation Area because the former was a younger stand. Most of the points at Point Reyes were located within the Vision Fire area. This area burned in 1995, eight years prior to our sampling. *Baccharis* responds to fire by putting out new shoots so that younger stands of Baccharis tend to have a greater number of stems per unit area though the stems are much smaller (McBride 1964). Older stands tend to have fewer larger stems, and are more likely to be rooted outside of the plot.

Estimated LAI was the least valuable predictor tested. There was no linear relationship found between estimated LAI and measured biomass. The highly layered growth form of *Baccharis* may be one of the reasons for the failure of this technique to predict biomass. The existence of a diverse understory extending into the *Baccharis* canopy may have also contributed to the variability in this method of measurement.

The multiple linear regression model that included both crown canopy height and basal area versus biomass had the greatest predictive value based on the adjusted R^2, but it was only slightly better than the model that included crown canopy height alone versus biomass. Since the addition of basal are only marginally increased the predictive power to the regression, the additional effort required to collect basal area data does not seem warranted.

The model developed for this study is applicable only to coastal *Baccharis* communities. However, a similar approach could be tested in other shrub types. As canopy height is the easiest variable to measure, we suggest testing its relationship with biomass in other shrub types in the hope that it will be equally acceptable. It may be that basal area would be a more effective predictor in some shrub types. The data presented in this paper are a first step toward developing predictive tools and fuel models for coastal shrub communities. Further research will be needed to develop complete fuel models for this and other coastal shrub types.

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