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Article

Ecuaciones para estimar biomasa total de candelilla (*Euphorbia antisyphilitica* Zucc.) en Chihuahua

Equations to estimate aerial biomass of *candelilla* (*Euphorbia antisyphilitica* Zucc.) in *Chihuahua*

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Abstract

Candelilla (*Euphorbia antisyphilitica* Zucc.) is a shrub that grows in the arid zones of northern Mexico. This species is harvested for the purpose of extracting a wax that it produces in response to water stress. In order to authorize the harvesting of plants, it is necessary to estimate their biomass indirectly through predictive equations. The objective of this study was to generate allometric equations to estimate the biomass of *candelilla* based on morphometric variables. The work was carried out in the region of *Aldama* and *Coyame del Sotol* in northeastern *Chihuahua*, Mexico. A selective and destructive sampling of 198 individuals of *candelilla* was applied, which were obtained in *ejidos* with forest management programs in force. Four models and different combinations of biomass predictor variables were tested to fit the best equation. Variables were transformed to logarithmic scale. The Schumacher and Hall model was selected in the logarithmic form determined by the crown diameter and base diameter of the plant, since it exhibited the best statistical adjustments (R^2_{adj}=0.83), as well as by the root mean square of the error (*RMSE*=0.042), and the model parameters were significant (p<0.0001) in their correction of the regression assumptions. The equation thus obtained is reliable for estimating the biomass of *candelilla* in the northeastern state of *Chihuahua,* Mexico.

Key words: Shrub biomass, *Candelilla* wax, allometric equations, models, biomass prediction, arid zones.

Resumen

La candelilla (*Euphorbia antisyphilitica*) es un arbusto que crece en las zonas áridas del norte de México. Esta especie se cosecha para extraer una cera que produce como respuesta al estrés hídrico. Para autorizar la recolección de las plantas, es necesario realizar estimaciones indirectas mediante ecuaciones predictivas de su biomasa. El objetivo del presente estudio fue generar ecuaciones alométricas para estimar biomasa de candelilla a partir de variables morfométricas. El trabajo se llevó a cabo en la región de Aldama y Coyame del Sotol en el noreste de Chihuahua, México. Se aplicó un muestreo selectivo y destructivo de 198 individuos de candelilla, los cuales se obtuvieron en ejidos con programas de manejo forestal vigente. Para ajustar la mejor ecuación se probaron cuatro modelos y diferentes combinaciones de variables predictoras de biomasa. Las variables se transformaron a escala logarítmica. Se seleccionó el modelo de *Schumacher* y *Hall* en la forma logarítmica con el uso del diámetro de copa y diámetro de la base de la planta, ya que fue el que presentó los mejores ajustes estadísticos (R^2_{adj}=0.83), la raíz del cuadrado medio del error (*RCME*=0.042), y los parámetros del modelo fueron significativos (p<0.0001) en su corrección de los supuestos de regresión. La ecuación obtenida es confiable para estimar biomasa de candelilla en el noreste del estado de Chihuahua, México.

Palabras clave: Biomasa de arbustos, cera de candelilla, ecuaciones alométricas, modelos, predicción de biomasa, zonas áridas.

Introduction

Candelilla (*Euphorbia antisyphilitica* Zucc.) reproduces by rhizomes, forming clusters of stems in patches of plants that grow in the semi-desert of northern Mexico (Arato *et al.*, 2014). As a mechanism to tolerate water deficit, this species produces a natural wax which is harvested for commercialization in national and international markets (Rojas *et al.*, 2011; Muñoz-Ruiz *et al.*, 2016).

In Mexico, *candelilla* harvesting is carried out mainly by inhabitants of villages in the arid zones of the states of *San Luis Potosí*, *Zacatecas*, *Coahuila* and *Chihuahua* (Villa-Castorena *et al.*, 2010; Becerra-López *et al.*, 2020). Extraction procedures, biomass estimation, harvesting intensities, and regeneration of the taxon have been studied for conservation and management purposes, since alterations in its distribution and abundance are caused by inappropriate use and by the influence of climate change (Vargas-Piedra *et al*., 2020).

The generation of allometric equations to estimate biomass or volumes is a widely studied topic for tree species in temperate and tropical forests, not only in Mexico, but also internationally (Vargas-Larreta *et al*., 2017; Martínez-Domínguez *et al.*, 2020; Martínez-Sánchez *et al.*, 2020). However, in shrub taxa and plants from semi-arid zones, the generation of these equations is little studied, even for species that are commercially exploited (Flores-Hernández e*t al.*, 2020; Villavicencio-Gutierrez *et al.*, 2020). In addition, it is necessary to develop them at the level of ecological regions, due to the wide variation of environmental conditions in which the semi-desert taxa grow; such is the case of *candelilla* (Hernández-Ramos *et al.*, 2019; Luo *et al.*, 2020; Vargas-Piedra *et al.*, 2020).

Prominent among the published works related to equations for estimating *candelilla* biomass —generated from data of average plant height and crown diameters— are those produced for certain regions in the state of *Coahuila* (Flores del Angel, 2013). Recently, Hernández-Ramos *et al*. (2019) have documented equations for some municipalities in the state of *Coahuila* with acceptable adjustments in the statistical estimators, allowing reliable estimation of the biomass of the species in these regions; however, there are no scientifically valid equations for *Chihuahua.*

The objective of this study was to generate allometric equations to estimate total biomass using morphometric variables of *Euphorbia antisyphylitica* for the region of *Aldama* and *Coyame del Sotol* in northeastern *Chihuahua,* Mexico.

Materials and Methods

Study area

The research was carried out in *Coyame del Sotol* and A*ldama* municipalities in the state of *Chihuahua*, Mexico (Figure 1). The predominant shrub vegetation is composed of desert microphyllous and rosetophytic shrubs, with a predominance of *Euphorbia antisyphilitica, Agave lechuguilla* Torr.*, Larrea tridentata* DC. Coville, and *Dasylirion* sp. (Granados-Sánchez *et al*., 2011). The altimetric altitudes of the area range between 940 and 1 500 m; the average annual rainfall is 200 to 400 mm and the average annual temperature is 24 °C (Granados-Sánchez *et al.*, 2011; González-Medrano, 2012).

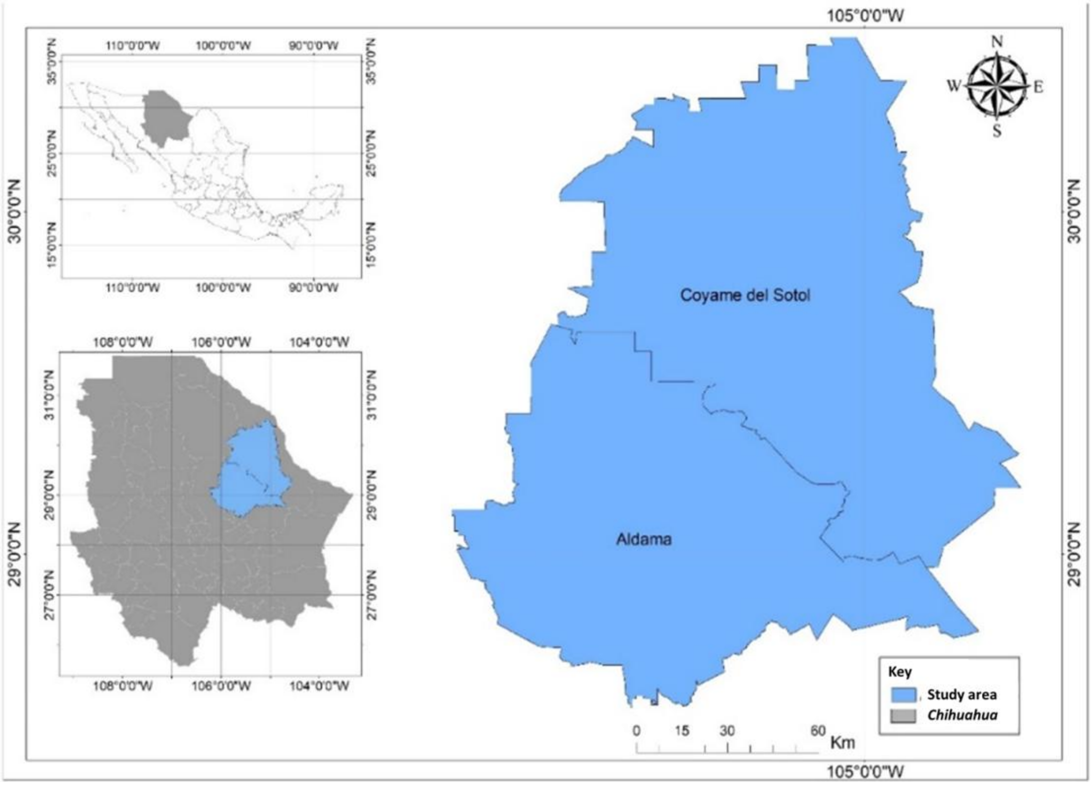

Figure 1. Location of the study area in the municipalities of *Aldama a*nd *Coyame del Sotol* in the state of *Chihuahua*, Mexico.

Data collection

The data were collected in *ejidos* and communities with currently valid technical studies on the use of *candelilla* (Table 1). For this work, the term "plant" is understood as a compact colony of catkins growing in independent patches, with at least 20 cm of separation between the bases of the colonies. Individuals were selected according to their health and size characteristics; diseased or sparse plants were avoided. Samples were obtained considering the variability of growth conditions that exist in plant populations. A destructive measurement procedure was carried out on 198 plants, distributed among seven *ejidos* with forest harvesting permits for *candelilla*. Morphometric variables were measured for each specimen: mean total height (*Mth*), average height of the tips of the shrub's crown, without considering the central height of the plant, which is usually higher; total height (*Th*), total height of the plant including the longest stem of the central portion of the crown; base diameter (*Bd*), diameter of the base of the plant measured 10 cm above the soil surface; crown diameter (*Cd*), average of the smallest and largest diameter of the crown width measured perpendicularly in north-south and east-west directions. Subsequently, each plant was extracted to obtain the weight of total green biomass (kg) including the root (Villavicencio-Gutiérrez *et al*., 2018).

Table 1. Distribution of samples of *Euphorbia antisyphilitica* Zucc. populations in the study area.

Municipality	Plots	Samples
Aldama	*Chorreras*	92
Coyame del Sotol	*Cañón de Barrera*	58
	El Táscate	19
	Francisco Portillo	6
	San Pedro	23

Total	198

Database

In the laboratory, the mean crown diameter (*Cd*) and crown cover (*Cc*) variables were estimated, the latter was calculated as the surface area of a circle with the mean crown diameter.

Descriptive summary of variables

Table 2 shows that the biomass of *candelilla* plants ranged from 0.09 to 12.89 kg per plant. The wide range in the size of the sampled plants was also observed, which allowed the use of the resulting equation for most of the plant sizes to be found in the field.

Table 2. Statistical summary of *Euphorbia antisyphilitica* Zucc. in the municipalities of *Coyame del Sotol* and *Aldama*, state of *Chihuahua*.

Variable	**n**	**Minimum**	**Maximum**	**Mean**	***SD***	***CV* (%)**
Bd (cm)	198	7	91.00	29.20	18.41	63.05
Th (cm)	198	17	105.00	46.43	15.33	33.02
Mth (cm)	198	10	80.00	30.00	11.05	36.83
Cd (cm)	198	14.5	147.50	50.53	25.88	51.22
Cc (m^2)	198	0.02	1.71	0.25	0.27	108.00
Biomass(kg)	198	0.09	12.89	1.85	2.33	125.95

Bd = Base diameter; *Th* = Total height; *Mth* = Mean height; *Cd* = Crown diameter; *Cc* = Crown cover; n = Sample size; *SD* = Standard deviation; *CV* = Coefficient of variation.

Selection of predictor variables

Pearson's correlation test was performed including all variables in order to determine their relationship with plant biomass. The purpose is to identify the variables correlated with biomass and the predictor variables. Distribution plots were used to visualize the relationship between the dependent variable (biomass) and the independent variables (crown diameter, base diameter, crown cover and height) (figures 2 and 3).

	Biomass	Bd	Cc	Cd	Mth
Bd	**0.80**				
Cc	**0.86**	**0.85**			
Cd	**0.85**	**0.90**	**0.97**		
Mth	**0.53**	**0.53**	**0.55**	**0.62**	
Th	**0.44**	**0.46**	**0.48**	**0.55**	**0.90**

Figure 2. Correlation test of morphometric variables and *candelilla* biomass.

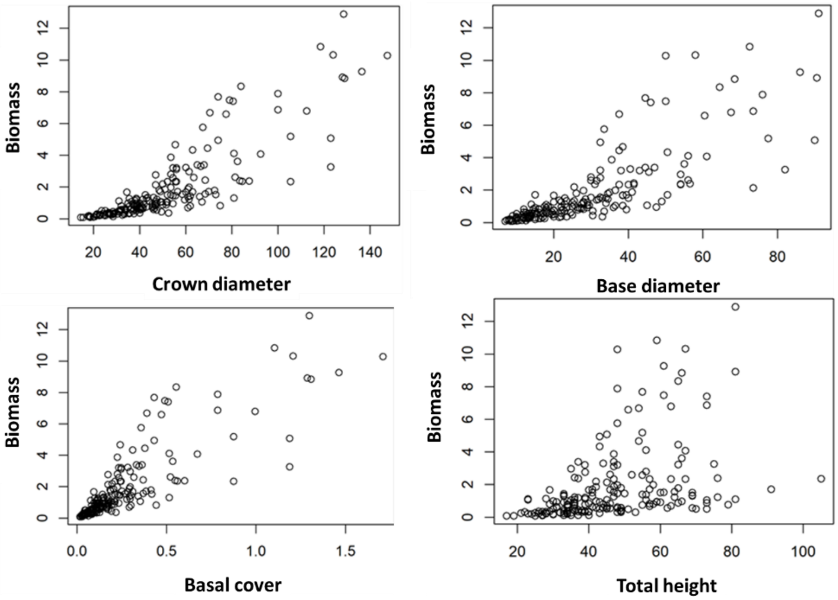

Figure 3. Relationship of biomass with predictor variables of *Euphorbia antisyphilitica* Zucc.

Model selection

Equations with flexibility criteria with different combinations of variables were selected for the purpose of determining the biomass of *E. antisyphilitica* (Table 3). These equations have allowed good biomass predictions for several forest species (Návar, 2010; Noulèkoun *et al.*, 2018; Altanzagas *et al.*, 2019). In the allometric biomass studies, error variances for nonlinear equations based on arithmetic units are not constant (heteroscedasticity) for all observations (Chave *et al*., 2005). This issue can be addressed by means of logarithmic transformations, which are one of the most widely used methods for reducing the influence of errors (Moussa and Mahamene, 2018; Zhao *et al*., 2018). Consequently, logarithmic equations were used to estimate the *candelilla's* biomass (Table 3). Allometric equations in their logarithmic form, the predictions lead to a systematic bias; in order to minimize this, the correction factor (*CF*) was calculated for each model (Sprugel, 1983).

Table 3. Proposed logarithmic equations for determining the biomass of *Euphorbia antisyphilitica* Zucc.

Eq.	Logarithmic equation	Original	Type

		equation	
1.1	$ln(B) = ln\ (B_0) + (B_1)\ ln(Dc)$	$B = \beta_0 Dc^{B_1}$	Allometric
1.2	$ln(B) = ln\ (B_0) + (B_1)\ ln(Ca)$	$B = \beta_0 Ca^{B_1}$	Allometric
1.3	$ln(B) = ln\ (B_0) + (B_1)\ ln(Db)$	$B = \beta_0 Db^{B_1}$	Allometric
2.1	$ln(B) = ln\ (B_0) + B_1\ ln(Db) + B_2\ ln(At)$	$B = \beta_0 Db^{B_1}\ At^{B_2}$	*Schumacher* and *Hall*
2.2	$ln(B) = ln\ (B_0) + B_1\ ln(Dc) + B_2\ ln(Db)$	$B = \beta_0 Dc^{B_1}\ Db^{B_2}$	*Schumacher* and *Hall*
2.3	$ln(B) = ln\ (B_0) + B_1\ ln(Db) + B_2\ ln(Atm)$	$B = \beta_0 Db^{B_1}\ Atm^{B_2}$	*Schumacher* and *Hall*
3.1	$ln(B) = ln\ (B_0) + (B_1)\ ln(Dc^2 * At)$	$B = \beta_0 (Dc^2 * At)^{B_1}$	*Spurr*
3.2	$ln(B) = ln\ (B_0) + (B_1)\ ln(Dc^2 * Db)$	$B = \beta_0 (Dc^2 * Db)^{B_1}$	*Spurr*
3.3	$ln(B) = ln\ (B_0) + (B_1)\ ln(Db^2 * Dc)$	$B = \beta_0 (Db^2 * Dc)^{B_1}$	*Spurr*
4.1	$ln(B) = ln\ (B_0) + (B_1)\ ln(At * Ca)$	$B = \beta_0 (At * Ca)^{B_1}$	*Spurr*
4.2	$ln(B) = ln\ (B_0) + (B_1)\ ln(Dc * Db)$	$B = \beta_0 (Dc * Db)^{\beta_1}$	*Spurr*

Fuente: Návar, 2010; Noulèkoun *et al.*, 2018; Altanzagas *et al.*, 2019.

Eq = Equation; *B* = Biomass; *B0*, *B1* and *B2* = Model parameters; *nl* = Natural logarithm.

$$CF = exp\left(\frac{SEest^2}{2}\right)$$

Where:

CF = Correction factor

SEest = Standard error of estimation

exp = Exponential function

Statistical analysis

The models were fitted using the Ordinary Least Squares method (OLS) (Montgomery *et al.*, 2021). The selection of the model was based on equation-fitting criteria, specifically the significance of the parameters ($p \leq 0.05$). In addition, the evaluation of the equations considered the adjusted coefficient of determination (R^2_{adj}), the root mean square error (*RMSE*), the Akaike information criterion (*AIC*), the Bayesian information criterion (*BIC*), and the mean absolute percentage error (*MAPE*) (Picard *et al.*, 2015; Islam *et al*., 2021). Subsequently, in order to validate the equations, the assumptions of the regressions were verified according to their predictions; normality was verified with the Lilierfors test, while compliance with homoscedasticity was evaluated with the Breusch-Pagan test (Villavicencio-Gutiérrez *et al*., 2018; Flores-Hernández *et al.*, 2020; Villavicencio-Gutierrez *et al.*, 2020). The autocorrelation correction was performed using the cochrane.orcutt method (Kutner *et al.*, 2005) with the orcutt library of R Project, which provides for a continuous-time autoregressive model (Quiñonez-Barraza *et al*., 2015). Finally, the variance inflation factor (*VIF*) was used to detect multicollinearity (Mahmood *et al.*, 2019). All statistical and graphical analyses were performed with the lm and plot functions in the R Project software (R Core Team, 2021).

Results

Basic statistics of the morphometric variables

The result of the Pearson correlation analysis shows that the variables that registered the highest correlation with biomass were crown cover (*r*=0.86), crown diameter (*r*=0.85) and base diameter (*r*=0.80) (Figure 2). However, in the linear regression analysis, all selected variables were used to obtain the best fits.

Biomass equations

The estimated parameters were significantly different from zero at a significance level of 5 % (p<0.0001). The fit statistics (R^2_{adj}, *RMSE*, *AIC* and *BIC*) exhibited similar values in the different equations (Table 4). In keeping with the selection criteria, equations 2.2 and 3.2 were selected to estimate the biomass, given that they both had the highest R^2_{adj} (0.84) and registered the lowest values for the *RMSE*, *AIC* and *BIC*. The regression assumptions were verified; the Lillierfos test showed normality of the residuals, while the Lillierfos test showed normality of the residuals: *D*=0.047, *p* value=0.345 and *D*=0.039, *p* value=0.0641 for equations 2.2 and 3.2, respectively (Table 5). The Breusch-Pagan test showed a slight presence of heteroscedasticity: *BP*=9.180, *p* value=0.050 and *BP*=8.697, *p* value=0.003, for equations 2.2 and 3.2, respectively. The Durbin-Watson test was 1.34 for the two equations, indicating that there was some consideration of autocorrelation between the variables. In view of this evidence, the equations were corrected in order to obtain reliable estimates in the prediction of the *candelilla's* biomass (Table 5).

Table 4. Estimated parameter values and their goodness-of-fit statistics of the logarithmic equations for predicting biomass in *Euphorbia antisyphilitica* Zucc.

Equation	Parameter	Estimator	Standard error	*t* value	*p* value	Variable	R^2_{adj}	*RMSE*	*AIC*	*BIC*	*CF*
1.1	*B1*	-8.12	0.27	-30.05	0.0001	*Cd*	0.82	0.47	268.38	278.25	1.12
	B2	2.13	0.07	30.29	0.0001						
1.2	*B1*	1.96	0.07	26.91	0.0001	*Cc*	0.82	0.47	268.38	278.25	1.12
	B2	1.06	0.03	30.29	0.0001						
1.3	*B1*	-5.19	0.20	-25.01	0.0001	*Bd*	0.77	0.54	323.30	333.17	1.16
	B2	1.62	0.06	25.45	0.0001						

2.1	*B1*	-7.04	0.41	-16.803	0.0001	*Bd*, *Th*	0.79	0.51	301.59	314.74	1.14
	B2	1.45	0.06	20.752	0.0001						
	B3	0.63	0.12	4.981	0.0001						
2.2*	*B1*	-7.46	0.28	-25.741	0.0001	*Cd*, *Bd*	0.84	0.45	247.66	260.81	1.10
	B2	1.46	0.15	9.676	0.0001						
	B3	0.58	0.12	4.87	0.0001						
2.3	*B1*	-6.66	0.35	-18.643	0.0001	*Bd*, *Mth*	0.79	0.51	302.22	315.37	1.14
	B2	1.42	0.07	19.427	0.0001						
	B3	0.62	0.12	4.911	0.0001						
3.1	*B1*	-9.58	0.35	-27.32	0.0001	Cd^2*Th	0.79	0.51	299.75	309.61	1.14
	B2	0.84	0.03	27.47	0.0001						
3.2*	*B1*	-7.32	0.22	-32.39	0.0001	Cd^2*Bd	0.84	0.45	246.28	256.15	1.10
	B2	0.677	0.02	32.39	0.0001						
3.3	*B1*	-6.26	0.21	-29.21	0.0001	Bd^2*Cd	0.82	0.48	275.91	285.78	1.12
	B2	0.614	0.02	29.60	0.0001						
4.1	*B1*	-1.63	0.06	-23.45	0.0001	*Th**Cc*	0.79	0.51	299.75	309.61	1.14
	B2	0.84	0.03	27.4	0.0001						
4.2	*B1*	-6.80	0.21	-31.04	0.0001	*Cd**Bd*	0.83	0.46	256.67	266.53	1.11
	B2	0.97	0.03	31.39	0.0001						

R^2_{adj} = Adjusted coefficient of determination; *RMSE* = Root mean square error; *AIC* = Akaike information criteria; *BIC* = Bayesian information criterion; *CF* = Correction factor; *Bd* = Base diameter; *Cd* = Crown diameter; *Th* = Total height; *Mth* = Mean height; *Cc* = Crown cover; * = Selected model.

Table 5. Assumptions of normality, heteroscedasticity, and inflation value of the equations tested.

Equation	**Lilierfors**	***p* value**	**Breusch Pagan**	***p* value**	**Durbin Watson**	**VIF**

1.1	0.042	0.521	9.227	0.002	1.350	
1.2	0.042	0.521	9.227	0.002	1.357	
1.3	0.039	0.632	1.102	0.293	1.299	
2.1	0.042	0.507	3.181	0.203	1.193	1.342
2.2	0.047	0.345	9.180	0.050	1.346	5.186
2.3	0.031	0.900	1.728	0.410	1.260	1.469
3.1	0.040	0.581	5.910	0.015	1.028	
3.2	0.039	0.641	8.697	0.003	1.340	
3.3	0.030	0.910	4.027	0.044	1.308	
4.1	0.040	0.580	5.910	0.015	1.028	
4.2	0.042	0.510	6.448	0.011	1.322	

The correction was performed with the Cochrane Orcutt test. Correcting for autocorrelation led to reliable estimates for biomass prediction (Table 6). Durbin-Watson test increased 2.19 for the two selected equations. The Breusch-Pagan test indicated the absence of heteroscedasticity: *BP*=3.689, *p* value=0.15 and *BP*=3.286, *p* value= 0.47 for equation 2.2 and 3.2, respectively.

Table 6. Estimates obtained by correcting the autocorrelation and heteroscedasticity of equations 2.2 and 3.2.

Equation	Parameter	Estimator	Standard error	*t* value	*p* value	R^2_{adj}	*RMSE*	*CF*
2.2	B1	-7.03	0.27	-25.157	0.0001	0.83	0.42	1.09
	B2	1.36	0.14	9.484	0.0001			
	B3	0.57	0.11	4.897	0.0001			
3.2	B1	-6.93	0.23	-30.134	0.0001	0.83	0.42	1.09
	B2	0.64	0.02	30.814	0.0001			

R^2_{adj} = Adjusted coefficient of determination; *RMSE* = Root mean square error; *CF* = correction factor.

The predictive capacity of model 2.2 showed a mean absolute percentage error of 3.6 %, and of 3.8 % for equation 3.2. Thus, the analyzed criteria favor equation 2.2 for estimating the green biomass of *candelilla*. The estimates obtained are alternatives for predicting *candelilla* biomass using the inverse transformation to a logarithmic scale; therefore, we suggest using the following equation for the estimation of the biomass of in the study region:

$$B = exp\left(-7.03 + 1.36 * nl(Cd) + 0.57 * nl(Bd)\right) * \ 1.15 \qquad Eq. 2.2$$

Where:

B = Biomass (kg)

nl = Natural logarithm

exp = Exponential function

Cd = Crown diameter (cm)

Bd = Base diameter (cm).

Discussion

The independent variables of *candelilla* plants showed a good correlation with biomass, mainly crown cover, crown diameter and base diameter. Total height and average height exhibited a weaker relationship. In this regard, it should be noted that, unlike in most tree species, whose biomass and volume prediction is made with data on the height and diameter of individuals, in shrub taxa there are other predictor variables that depend on the shape of the plant.

For example, Pando-Moreno *et al.* (2004) tested several variables for predicting the biomass of lechuguilla (*Agave lechuguilla* Torr.) and determined that bud volume, as an independent variable, had a higher correlation coefficient than bud biomass. For their part, Villavicencio-Gutierrez *et al.* (2018) identified a reliable relationship between the average crown diameter and the base diameter with the biomass of *Lippia graveolens* Kunth in arid zones, using the Schumacher and Hall equation. It stands out that, in shrub species with irregular shapes, avoiding multicollinearity and performing an analysis of variables is more necessary in order to obtain those that best predict the biomass (Daryanto *et al.*, 2013; Dai *et al.*, 2020).

In this study, allometric equations using the variables crown diameter and base diameter led to a more accurate estimation of the biomass of *candelilla*. These equations had a low *RMSE* (0.42) and a statistically acceptable R^2_{adj} (0.82) (p<0.0001). In this regard, some studies indicate that crown diameter is a reliable variable for estimating shrub biomass in arid and semi-arid zones (Ali *et al.*, 2015; Sione *et al.*, 2019; Aranha *et al.*, 2020; Chieppa *et al.*, 2020).

The prediction of the biomass or volume of shrub species usually presents acceptable values. However, test statistics commonly present lower values than the prediction of the biomass of tree taxa, especially of conifers, which generally maintain conical and solid shapes, as opposed to shrubs, which are highly branched and not very uniform (Pando-Moreno *et al.*, 2004; Zhang *et al.*, 2016; Vargas-Larreta e*t al*., 2017; Yao *et al.*, 2021). In this sense, the present study was no exception, since the maximum values of the coefficient of determination (R^2_{adj}) were 0.84, compared to the model equations for tree species, whose coefficients are generally above 0.90 (Vargas-Larreta *et al*., 2017).

In the documented case of *candelilla*, the model of Schumacher and Hall (Equation 2.2) in its logarithmic form predicted a *candelilla* biomass with statistically acceptable coefficients. The general forms of these equations have been used in other research studies in arid and semi-arid environments (Návar *et al.*, 2004; Flores-Hernández *et al.*, 2020), its effectiveness is ratified. In addition, it is important to note that the crown and base diameters of the shrubs are easy to measure in *candelilla*, which grows in colonies or small groups of stems forming wide patches from the base (Flores-del Angel *et al.*, 2013; Bañuelos-Revilla *et al.*, 2019). Finally, the estimates obtained can be used to calculate the areal biomass of *E. antisyphilitica* for the arid zones of the state of *Chihuahua*.

Conclusions

The allometric equation of Schumacher and Hall in its logarithmic form can be used to estimate the biomass of *Euphorbia antisyphilitica* in the northeastern region of *Chihuahua*. The selected equation includes easily measured morphometric variables such as the crown variable and the base diameter of the plants.

The models tested in this study are recommended for estimating the green biomass of *candelilla,* which is required in technical studies and management programs of the species in *Aldama* and *Coyame del Sotol* municipalities in northeastern *Chihuahua*, Mexico.

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Conflict of interest

The authors declare no conflict of interest with any person or institution.

Contributions by author

Margarito Maldonado Ortiz and Martín Martínez Salvador: data processing and analysis, planning and drafting of manuscript; Pablito Marcelo López Serrano: overall project coordination and information storage support; Ricardo D. Valdez Cepeda: data analysis; Ricardo Mata González: review and editing of the contribution; Fabián García González: review and editing of the manuscript.

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