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Article

Modelo para predecir biomasa foliar seca de *Litsea parvifolia* (Hemsl.) Mez.

Model for estimating *Litsea parvifolia* (Hemsl.) Mez. dry leaf biomass

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Resumen

Litsea parvifolia es un arbusto, perenne de la familia Lauraceae, cuya biomasa foliar es su componente principal. Sus hojas se aprovechan y comercializan en el sureste de Saltillo y alrededores. En fresco, tiene uso culinario y medicinal; en seco, como condimento. Con el propósito de generar información básica para la regulación de su aprovechamiento, se planteó seleccionar un modelo alométrico para predecir la biomasa foliar seca y elaborar una tabla de producción para arbustos en pie. Se evaluaron algunas poblaciones naturales, en las que se registró la altura total (H) y diámetro promedio (Dp) de todos los individuos en pie y se determinó la biomasa foliar seca (Bfs). Se probaron nueve modelos alométricos mediante el procedimiento PROC MODEL en SAS 9.4, para elegir aquel con el mayor coeficiente de determinación ajustado ($R^2_{aj.}$); el valor más bajo en la raíz cuadrada media del error ($RCME$), en el coeficiente de variación (CV) y en la suma de cuadrados de los residuales (SCR); además de la significancia de sus parámetros ($P \leq 0.05$). El Dp y la H se correlacionaron con la Bfs . El modelo Schumacher-Hall no lineal es confiable estadísticamente ($p < 0.0001$), registra los mejores estadísticos, con presencia de heteroscedasticidad, efecto corregido con regresión ponderada con estructura de varianza $(Dp^2H)^{-0.5}$, una $R^2_{aj.}$ de 0.82, S_{xy} de 18.41 g y un CV de 44.93 %. El modelo puede usarse para predecir la producción de Bfs en sitios con características ecológicas similares al área de estudio.

Palabras clave: Alometría, biomasa, hoja seca, manejo forestal, no maderable, regresión ponderada.

Abstract:

Litsea parvifolia is an ever-green shrub of the Lauraceae family whose foliar biomass is its main component. Its leaves are harvested and marketed in and around the southeastern region of Saltillo municipality, Coahuila State. Fresh, it has culinary and medicinal use; dry, it is used as condiment. In order to regulate its use and determining its stock, an allometric model was selected to estimate the dry foliar biomass and the elaboration of a production table of the standing shrubs was planned as well. Natural populations were evaluated, recording the total height (H , cm) and mean diameter (Dp , cm) of the shrub crown, considering all categories of height and cover of standing shrubs and dry leaf biomass (Bfs , g). Ten allometric models were evaluated using the PROC MODEL procedure in SAS, version 9.4. Dp and H are correlated with laurel Bfs . The Schumacher-Hall model in its non-linear form is statistically reliable ($p < 0.0001$) as it records the best statistics, with presence of heteroscedasticity, corrected effect with a weighted regression with variance structure $(Dp^2H)^{-0.5}$, obtaining an $R^2_{aj.}$ of 0.82, S_{xy} of 18.41 g and a CV of 44.93 %. The model can be used to estimate the production of Bfs in places with similar ecological characteristics to the study area.

Key words: Allometry, biomass, dry leaf, forest management, non-timber, weighted regression.

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Introduction

Non-timber forest products (NTFPs) are vastly important as goods and services, primarily in rural communities, as they have a variety of uses —nutritional, cultural, medicinal, and industrial—, and, in general, they are in high demand in foreign trade (Chandrasekharan *et al.*, 1996).

The native distribution area of *Litsea parvifolia* (Hemsl.) Mez. (*laurel*) is northeastern Mexico, with seven recognized species of this genus. It grows in humid areas, pine-oak forests, and semi-desert shrublands; it grows at altitudes of 1 000 to 3 000 m, but with a restricted distribution in the states of *Coahuila*, *Nuevo León* and *Tamaulipas* (Van Der Werff and Lorea, 1997; Jiménez-Pérez and Lorea-Hernández, 2009).

According to the *Codex Alimentarius* Commission of the United Nations' Food and Agriculture Organization (FAO) and the Mexican Official Norm PROY-NOM-000-SCFI/SADER-2019 on Spices and Cooking or Aromatic Herbs, dry Mexican bay leaves — whole, crushed or ground— are used in cooking due to their flavor, aroma and visual aspect, and their primary function is to provide a fragrant, aromatic or pungent seasoning to foods (CODEX, 2017).

From the medicinal point of view, it is prepared as an infusion tea in order to relieve digestive disorders such as diarrhea and indigestion, as well as fever and nervousness; in addition, its maceration in alcohol is used for healing rheumatism. In some cases, the plant is given a ceremonial and ornamental use (Jiménez-Pérez *et al.*, 2011).

Biomass is the amount of living organic matter present in the stems, leave and bark (aerial biomass), as well as in the roots (underground biomass) (Brown, 1997). In forest terms, biomass is utilized to determine the carbon content per unit of surface area and, thus, to calculate the fixing capacity of the ecosystems (Ordóñez *et al.*, 2015).

Allometric models are tools for predicting biomass components of the plant (leaves, branches, roots, etc.) based on one or more easily measured variables (diameter, height) and thus express their mean content at the genus or species level (Avery and Burkhart, 1983; Picard *et al.*, 2012; Gaillard *et al.*, 2013). A production table summarizes these calculations, whose

application, however, is restricted to regions with similar ecological characteristics to those of the area for which they were made (Ramos-Uvilla *et al.*, 2014).

Several allometric models have been generated in arid zones for predicting the biomass of trees and shrubs like *Prosopis glandulosa* Torr. (Méndez *et al.*, 2012), *Acacia pennatula* (Schltdl. & Cham.) Benth. (López-Merlín *et al.*, 2003), *Larrea tridentata* (DC.) Coville (Ludwig *et al.*, 1975), *Atriplex canescens* (Pursh) Nutt. var. *canescens* (Thomson *et al.*, 1998), *Lippia graveolens* Kunth (Villavicencio *et al.*, 2018), and in fiber producing species such as *Yucca carnerosana* Trel. (Villavicencio and Franco, 1992), *Agave lechuguilla* Torr. (Berlanga *et al.*, 1992; Velasco *et al.*, 2009) and *Nolina cespitifera* Trel. (Sáenz and Castillo, 1992), or even the weight of the stem or “cone” in *Dasyllirion cedrosanum* Trel. (Cano *et al.*, 2006).

Because leaves of *L. parvifolia* are one of the most exploited and commercialized components in arid zones, the objective of the present study was to determine the mensuration variable or variables of the plant that are directly correlated to dry leaf biomass, once the most suitable allometric model for predicting the weight of the dry leaves has been selected, and, based on it, to develop a production table that may serve to evaluate the natural Mexican bay populations existing in *Saltillo* municipality, *Coahuila* State, Mexico.

Materials and Methods

Study area

The study was carried out in *Cuauhtémoc ejido*, in *Saltillo*, *Coahuila*, located at 25°17'3.61" N and 100°56'57.99" W (RAN, 2018) (Figure 1). The soil type is Leptosol (Inegi, 2006 a); the climate is BS₁kw (semi-arid, temperate); the mean annual temperature ranges between 12 and 18 °C, and the precipitation, between 500 and 800 mm (Inegi, 2006b; Inegi, 2007; Inegi, 2008). The vegetation consists of conifer forests, rosetophile scrubs, sub-montane shrubs and grasslands (Profauna, 2008).

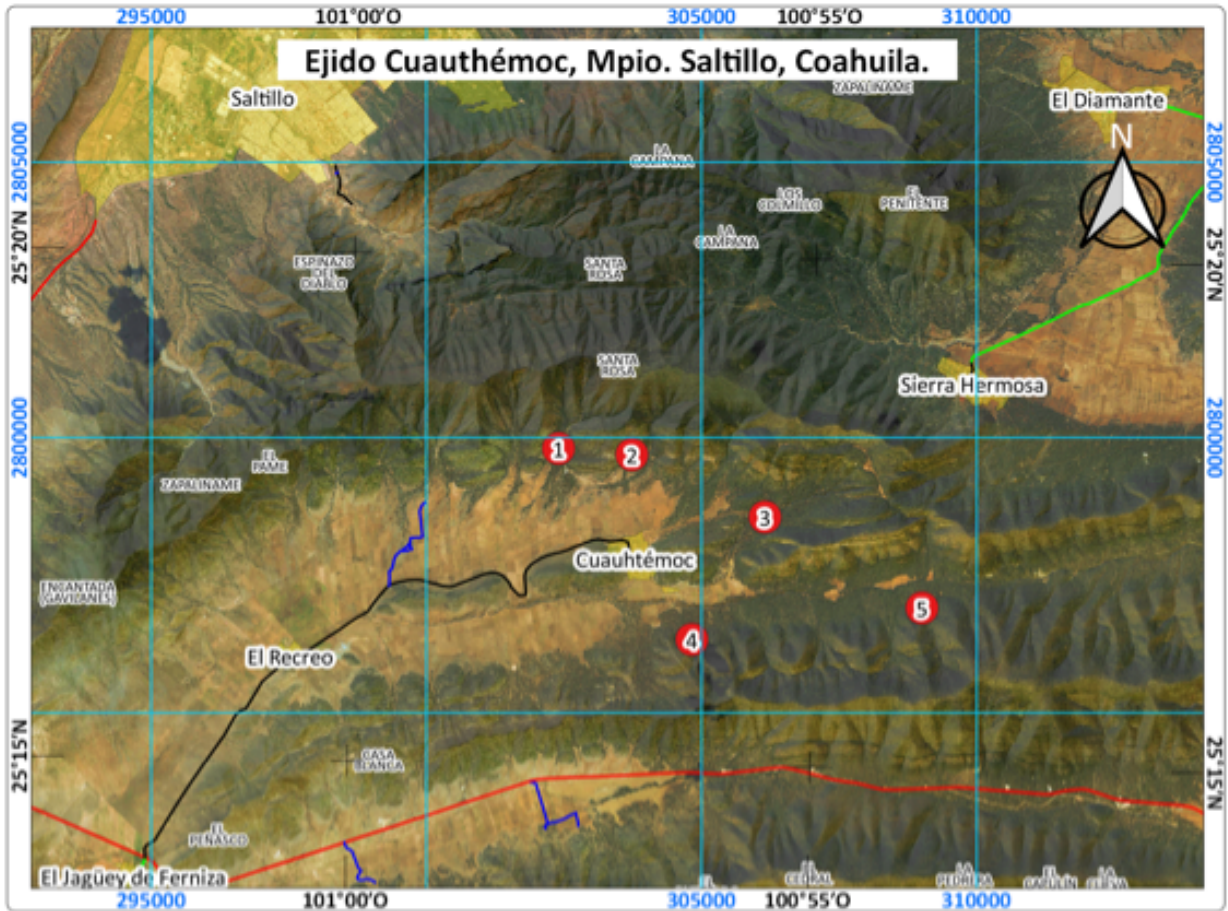


Figure 1. Geographical distribution of the localities where the *Litsea parvifolia* (Hemsl.) Mez. populations were assessed, in *Saltillo* municipality, *Coahuila*.

Sampling design and estimation of variables

According to a directed sampling, a total of 156 *L. parvifolia* plants were selected, considering all the categories of height and crown diameter. The measured variables were total height from ground level (H , cm), and larger (DM , from its acronym in Spanish) and smaller (Dm , from its acronym in Spanish) crown diameter, which were made with a 21601 Pretul[™] professional flexometer. The mean diameter (Dp , from its acronym in Spanish) of the leaf coverage of the shrub was estimated in terms of the measurement of two perpendicular diameters (DM and Dm) of each shrub, both of which

were expressed in centimeters (cm). A destructive sampling was applied, in which the stems and leaves of each selected plant were cut. The samples were kept in paper bags with their corresponding label and were subsequently dehydrated in the greenhouse of the *Saltillo* Experimental Station of the *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, INIFAP* at ambient temperature during five days, after which the stems were separated from the leaves. The dry leaf biomass (*Bfs*) was determined using an ADAM™ analytical scale with 0.001 g accuracy. Thus, the dependent variable was *Bfs*, and the independent variables, *H* and *Dp*.

Statistical analysis

The data of the dry leaf biomass and the variables height and mean diameter were analyzed using the PROC MODEL of SAS (Statistical Analysis System) software, version 9.4 (SAS, 2017), with Ordinary Least Squares (OLS) regression. Nine allometric models were fitted; these had been previously evaluated in similar studies on oregano (Villavicencio *et al.*, 2018), *lechuguilla* (Velasco *et al.*, 2009), mesquite (Méndez *et al.*, 2012), and acacias (López-Merlín *et al.*, 2003) (Table 1). These models provide a perfect description of the relationship between forest mensuration variables and the biomass.



Table 1. Models fitted for predicting the dry leaf biomass of *Litsea parvifolia* (Hemsl.) Mez. at *Cuauhtémoc ejido*, in *Saltillo*, *Coahuila*.

Model	Name	Equation
1	Allometric	$Bfs = \beta_0(DpH)^{\beta_1}$
2	Constant morphic coefficient	$Bfs = \beta_1(Dp^2H)$
3	Australian	$Bfs = \beta_0 + \beta_1(Dp^2) + \beta_2(H) + \beta_3(Dp^2H)$
4	Combined linear variable	$Bfs = \beta_0 + \beta_1(Dp^2H)$
5	Spurr	$Bfs = \beta_1(Dp^2H)^{\beta_2}$
6	Schumacher-Hall	$Bfs = \beta_0(Dp)^{\beta_1}(H)^{\beta_2}$
7	Potency	$Bfs = \beta_0(Dp)^{\beta_1}$
8	Takata	$Bfs = (Dp^2H)/((\beta_0) + \beta_1Dp)$
9	Thornber	$Bfs = \beta_0(H/Dp)^{\beta_1}(Dp^2H)$

Sources: Segura and Andrade (2008); Picard et al. (2012).

Bfs = Dry leaf biomass (g); Dp = Mean crown diameter (cm); H = Total height (cm);
 $B_0 \dots, \beta_n$ = Regression coefficients, Exp = Exponential of the expression.

Model selection criteria

The statistical parameters for the selection of the best model were: a higher value of the adjusted coefficient of determination ($adjR^2$), a lower value for the quadratic mean error ($RMSE$), the coefficient of variation (CV), and the quadratic sum of the residuals (QSR); also considered was the significance of its parameters ($P \leq 0.05$) (Segura and Andrade, 2008; Picard et al., 2012). The Shapiro-Wilk test for the verification of the normality of the residuals (Pedrosa et al., 2015) and the Durbin-Watson statistic (d) in order to detect the self-correlation (Gujarati and Porter, 2010). The presence of heteroskedasticity was corrected by performing a weighted regression, using the Dp and the H in various forms as weighting structures (Schreuder and Williams, 1998). The predictive capacity of the model was determined through the percentage mean error (EMP) and the added difference (DA) (Cruz and Uranga-Valencia, 2013):

$$EMP = \frac{1}{n} \sum_{i=1}^n \frac{(Y_i - Y_{est})}{Y_{est}} \times 100$$

$$DA = \frac{1}{n} \sum_{i=1}^n (Y_i - Y_{est})$$

Where:

EMP = Percentage mean error

Y_i = Observed values

Y_{est} = Estimated values

DA = Added difference

Results and Discussion

The average dry leaf biomass of *L. parvifolia* per plant in the study area was 40.99 g. with a variation of 1.80 to 246.32 g, and it became evident that the morphological variation and factors such as competition determined its production (Foroughbakhch *et al.*, 2009); furthermore, it is indicative of the productivity of the forest ecosystem as mentioned by Huff *et al.* (2018) (Table 2).



Table 2. Descriptive statistic of *Litsea parvifolia* (Hemsl.) Mez. at Cuauhtémoc ejido. Saltillo, Coahuila.

Variable	Average	Minimum	Maximum	DE	CV
<i>H</i> (cm)	71.25	27.00	201.00	26.59	37.32
<i>Dp</i> (cm)	53.54	16.50	120.50	22.09	41.26
<i>Bfs</i> (g)	40.99	1.80	246.32	44.05	107.47

H = Total height; *Dp* = Mean diameter per crown ($DM + Dm$) / 2; *Bfs* = Dry leaf biomass; *DE* = Standard deviation (g); *CV* = Coefficient of variation (%).

According to the results of the nine adjusted models: seven had a higher $adjR^2$ above 0.70, which indicates that the variability of the dry leaf biomass of *L. parvifolia* can be accounted for in 70 % by the average crown diameter and the total height of the plant. The S_{xy} varied from 17.56 to 25.81 g, and the CV was 42.84 to 62.96 % G (Table 3). According to the selection criteria, the Schumacher-Hall model (6) was the one that best estimated the foliar biomass of *L. parvifolia*.



Table 3. Regression coefficients and goodness-of-fit statistics of the models for predicting the dry leaf biomass of *Litsea parvifolia* (Hemsl.) Mez. at *Cuauhtémoc ejido*, *Saltillo*, *Coahuila*.

Model	Coefficient	Estimate	P value	$adjR^2$	S_{xy}	CV	QSR
1	β_0	0.0070	0.062	0.6568	25.81	62.96	93243.4
	β_1	1.0482	<0.0001				
2	β_1	0.0001	<0.0001	0.6794	24.94	60.86	87731.7
	β_0	-15.4778	0.0116				
3	β_1	0.0119	<0.0001	0.8391	17.67	43.11	43090.8
	β_2	0.1977	0.0206				
	β_3	0.0000	0.4754				
4	β_0	11.6173	<0.0001	0.7206	23.28	56.80	75898.5
	β_1	0.0001	<0.0001				
5	β_1	0.0039	0.0266	0.7754	20.95	51.11	61452.8
	β_2	0.7516	<0.0001				
	β_0	0.0029	0.0174				
6	β_1	2.0836	<0.0001	0.8411	17.56	42.84	42853.1
	β_2	0.2512	0.0006				
7	β_0	0.0043	0.0196	0.8275	18.29	44.63	46857.4
	β_1	2.2459	<0.0001				
8	β_0	3767.9430	<0.0001	0.7163	23.46	57.24	77069.7
	β_1	44.1444	<0.0001				
9	β_0	0.000138	<0.0001	0.7915	20.1176	49.08	56660.5
	β_1	-0.704540	<0.0001				

$adjR^2$ = Adjusted coefficient of determination; S_{xy} = Standard error of the model (g);
CV = Coefficient of variation (%); QSR = Quadratic sum of the residuals.

Due to its simplicity and to its good fit, the Schumacher-Hall model is widely utilized to predict the volume, the carbon content (Cruz *et al.*, 2016), and the leaf biomass in shrub taxa (Villavicencio *et al.*, 2018). In models generated for aromatic species such as oregano (Villavicencio *et al.*, 2018) and thyme (Belmonte and López, 2003), the variables height and diameter are also the best biomass predictors, as was the case of *L. parvifolia*.

The Durbin-Watson statistic (d) (2.03) with $n = 142$, $k = 3$, $\alpha = 0.05$, $d_L = 1.6$ (lower limit) and $d_U = 1.7$ (upper limit) proved that the residuals of the Schumacher-Hall model exhibited no self-correlation; this was not the case with the normality or with the variance homogeneity (Table 4). Therefore, a weighted regression was carried out using this same model as proposed by Walpole *et al.* (2012).

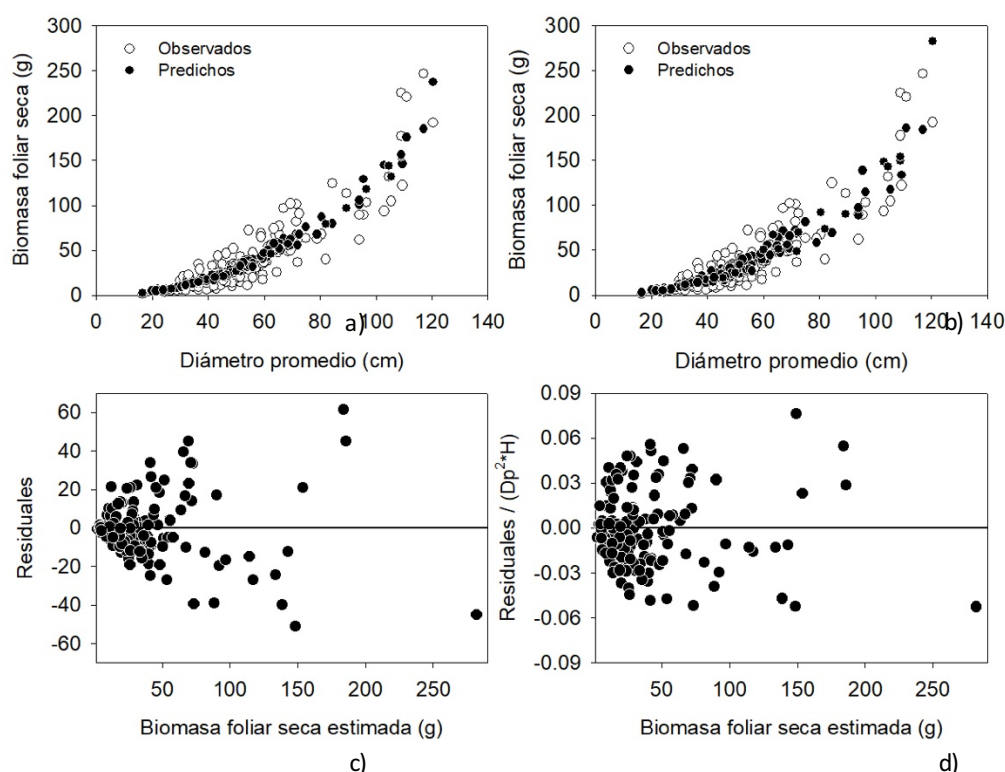
Table 4. Weighting factors for the Schumacher-Hall model, homoskedasticity tests, and tests of normality of the residuals.

<i>F.P.</i>	Variable	S_{xy}	$adjR^2$	DW	Heteroskedasticity		Normality	
					X^2	$p > X^2$	W	$p > W$
Dp^c	<i>Bfs</i>	17.75	0.8376	2.15	53.39	<0.0001	0.96	0.0006
	<i>Resid.</i>	0.97						
$(Dp * H)^c$	<i>Bfs</i>	17.83	0.8361	2.25	55.45	<0.0001	0.96	0.0002
	<i>Resid.</i>	0.98						
$k * Dp^c$	<i>Bfs</i>	18.82	0.8174	1.81	5.69	0.7702	0.95	<0.0001
	<i>Resid.</i>	1.02						
$k * (Dp * H)^c$	<i>Dlb</i>	19.26	0.8089	1.95	14.81	0.0962	0.94	<0.0001
	<i>Resid.</i>	1.02						
Dp	<i>Bfs</i>	17.63	0.8399	2.19	61.28	<0.0001	0.96	0.0002
	<i>Resid.</i>	2.01						
$Dp * H$	<i>Bfs</i>	18.04	0.8324	2.19	40.90	<0.0001	0.96	0.0008
	<i>Resid.</i>	0.23						
$Dp^2 * H$	<i>lBfs</i>	18.42	0.8252	2.03	16.20	0.0629	0.97	0.0011
	<i>Resid.</i>	0.03						
$(Dp^2 * H)^c$	<i>Bfs</i>	17.79	0.8368	2.22	54.88	<0.0001	0.96	0.0004
	<i>Resid.</i>	0.98						
$k * (Dp^2 * H)^c$	<i>Bfs</i>	19.23	0.8094	1.87	6.42	0.6977	0.94	<0.0001
	<i>Resid.</i>	1.02						

F.P. = Weighting factor; Dp^c = Average diameter of the leaf coverage of the shrub; H = Total height; c and k = parameters of the variance model; *Resid.* = Residuals; *Bfs* = Dry leaf biomass.

Weighted regression with variance structure

In order to correct the heteroskedasticity of the Schumacher-Hall model, several weighting factors were tested according to Álvarez-González (2007), Gómez-García (2013), and Pedrosa *et al.*, (2015); the variables Dp and H were utilized as a weighting factor ($F.P.$) for this purpose, using the PROC MODEL tool of the SAS software, and the term $(Dp^2 * H)$ was proven to satisfactorily correct the heteroskedasticity of the model. The $adjR^2$ and S_{xy} were similar with and without weighting (tables 3 and 4). The statistic W increased with the weighting, which suggested that the residuals are closer to a normal distribution (Table 4). The residuals exhibit heteroskedasticity when the model is not weighted (Figure 2c), and homoscedasticity when it is (Figure 2d).



Biomasa foliar seca estimada = Estimated dry leaf biomass; *Residuales* = Residuals; *Diámetro promedio* = Mean diameter; *Observados* = Observed; *Predichos* = Predicted.

Figure 2. Estimated dry leaf biomass of *Litsea parvifolia* (Hemsl.) Mez. without (a) and with weighting (b); estimated residuals without weighting (c) and with weighting factor (d).

Differences were observed between the predicted weighted and unweighted values, in absolute (*i.e.* observed minus predicted) terms. The weighted values overestimate the dry leaf biomass by 9.5 g, while the unweighted ones overestimate it only by 6.3 g, less than 0.10 % of the total. Nevertheless, fulfillment of the assumptions of the regression models (for the weighted model) is preferable, as it ensures efficient predictions. Because the Schumacher-Hall model corrects the heteroskedasticity completely and is statistically reliable ($P < 0.0001$), it can be utilized to predict the production of *L. parvifolia* dry leaf biomass.

The corrected goodness-of-fit statistics were: $adjR^2 = 0.8252$, estimation error = 18.42 g (Table 4), and statistical significance in all the parameters ($P \leq 0.05$). These results adjust to the requirements of Picard *et al.* (2012) for the selection of a model; furthermore, they are within the interval cited by Návar *et al.* (2002) and Návar *et al.* (2004) for 18 shrub species of the *Tamaulipan* shrub, where leaf biomass prediction models with $R^2 = 0.56$ to 0.93 , error = 0.026 to 0.396 kg, and C. V. = 14 to 81 % were generated. Similar values have also been documented for shrub taxa used as forage, as firewood, and for medicinal purposes, in which R^2 varies between 0.45 and 0.99 (Foroughbakhch *et al.*, 2005; Foroughbakhch *et al.*, 2009). Huff *et al.* (2018) register a S_{xy} of 33.2 to 441.9 g for shrubs. In most cases, the diameter and coverage were the independent variables utilized for predicting the production of leaf biomass; in the present study, the heteroskedasticity was corrected by including the height variable.

In the face of the lack of normality and the presence of heteroskedasticity, as in the case of *L. parvifolia*, authors like Gómez-García (2013) carried out a weighted regression with a variance model, based on the diameter, the height (D^2) and $(D^2H)^{-c}$ in *Betula pubescens* Ehrh. and *Quercus robur* L. Flores *et al.* (2018) utilized height (H) and FP in *Arbutus arizonica* (A. Gray) Sarg.; Schreuder and Williams (1998) suggested utilizing the variables diameter and height [D^2 and (D^2H)] interchangeably in tree species, as they provide similar results. Villavicencio *et al.* (2018) used the diameter and the height ($Dp * At$) in aromatic shrubs like oregano (*Lippia graveolens*).

Model for predicting *Litsea parvifolia* (Hemsl.) Mez. dry leaf biomass

Unweighted Schumacher-Hall model:

$$Bfs = 0.002887(Dp)^{2.083566}(H)^{0.251239} \quad 1)$$

Schumacher-Hall model corrected by a weighting factor:

$$Bfs = 0.00147(Dp)^{1.993821}(H)^{0.492306} \quad 2)$$

The results evidenced an added difference (*DA*) of 0.06 g of average error in the estimation of the dry leaf biomass per plant, with a mean percentage error (*EMP*) of 0.16 %. According to Prodan *et al.* (1997), an *EMP* of less than 1 % ensures the validity of the model; thus, the Schumacher-Hall model is adequate for the interval of observed values, and it is statistically effective for predicting the dry leaf biomass of *L. parvifolia*.

A double-entry table with an operation interval is 5 to 120 cm for both independent variables (*H* and *Dp*) based on the selected variables in the Schumacher-Hall model. Within this model, there are intervals every 5 cm in which the dry leaf biomass (*Bfs*) (g) of the standing *L. parvifolia* plants can be predicted (Table 5). This prediction table facilitates the quantification in the field and is easy to use.



Table 5. *Litsea parvifolia* (Hemsl.) Mez. dry leaf biomass (g) *Litsea parvifolia* (Hemsl.) Mez. for natural stands of Cuauhtémoc ejido, Saltillo, Coahuila.

Diameter (cm)	Height (cm)																							
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
5	0.1	0.1	0.1	0.2	0.2																			
10	0.3	0.5	0.5	0.6	0.7	0.8																		
15	0.7	1.0	1.2	1.4	1.6	1.7																		
20			2.2	2.5	2.8	3.1	3.3	3.5																
25				3.9	4.4	4.8	5.2	5.5	5.9															
30					6.3	6.9	7.5	8.0	8.4	8.9	9.3	9.7	10.1											
35						9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.2								
40						12.3	13.2	14.1	15.0	15.8	16.5	17.3	17.9	18.6	19.3	19.9	20.5	21.1						
45						15.5	16.7	17.9	18.9	19.9	20.9	21.8	22.7	23.5	24.4	25.1	25.9	26.6	27.4	28.1				
50							20.6	22.1	23.4	24.6	25.8	26.9	28.0	29.0	30.1	31.0	32.0	32.9	33.8	34.6	35.5	36.3	37.1	37.9
55							25.0	26.7	28.3	29.8	31.2	32.6	33.9	35.1	36.3	37.5	38.7	39.8	40.8	41.9	42.9	43.9	44.9	45.8
60								31.7	33.6	35.4	37.1	38.7	40.3	41.8	43.2	44.6	46.0	47.3	48.6	49.8	51.0	52.2	53.3	54.5
65									39.4	41.5	43.5	45.4	47.3	49.0	50.7	52.3	53.9	55.5	57.0	58.4	59.8	61.2	62.6	63.9
70									45.7	48.1	50.5	52.7	54.8	56.8	58.8	60.7	62.5	64.3	66.0	67.7	69.4	71.0	72.5	74.1
75									52.4	55.2	57.9	60.4	62.9	65.2	67.4	69.6	71.7	73.8	75.8	77.7	79.6	81.4	83.2	85.0
80									59.7	62.8	65.8	68.7	71.5	74.1	76.7	79.2	81.6	83.9	86.2	88.4	90.5	92.6	94.7	96.7
85									70.9	74.3	77.6	80.7	83.7	86.6	89.4	92.1	94.7	97.2	99.7	102.2	104.5	106.8	109.1	
90										83.3	86.9	90.4	93.8	97.0	100.1	103.2	106.1	109.0	111.8	114.5	117.1	119.7	122.3	
95											96.8	100.7	104.4	108.1	111.5	114.9	118.2	121.4	124.5	127.5	130.5	133.4	136.2	
100													115.7	119.7	123.6	127.3	130.9	134.5	137.9	141.3	144.5	147.7	150.9	
105															136.2	140.3	144.3	148.2	152.0	155.7	159.3	162.8	166.3	
110																153.9	158.3	162.6	166.8	170.8	174.8	178.6	182.4	
115																		177.7	182.2	186.6	191.0	195.2	199.3	
120																				198.4	203.2	207.9	212.5	217.0

Conclusions

The Schumacher-Hall model is the one that best predicts the dry leaf biomass of the standing *Litsea parvifolia* (Hemsl.) Mez. bushes, based on simple measurements of variables as the mean diameter of the crown and total height of the bush. The double-entry prediction table generated can be applied in areas where plants of this species occur with structures of similar diameter, height and climate conditions to those observed in this study.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Eulalia Edith Villavicencio-Gutiérrez: field data collection, drafting of the manuscript, result analysis, review and editing of the document; Santiago Mendoza-Morales: bibliographical research and modeling of results; Jorge Méndez González: result analysis, review and editing of the document.

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