ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.10, p.729-734, 2022
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n10p729-734

Leaf area estimation of *Congea tomentosa* using a non-destructive method[1]

Estimativa de área foliar de *Congea tomentosa* através de método não destrutivo

Marlon G. Dias[2], Débora Mela[3], Toshik I. da Silva[2*], João E. da S. Ribeiro[4], José A. S. Grossi[2], Affonso H. L. Zuin[2], Andressa C. P. Martinez[3] & José G. Barbosa[2]

[1] Research developed at Universidade Federal de Viçosa, Viçosa, MG, Brazil
[2] Universidade Federal de Viçosa/Departamento de Agronomia, Viçosa, MG, Brazil
[3] Universidade Federal de Viçosa/Departamento de Arquitetura e Urbanismo, Viçosa, MG, Brazil
[4] Instituto Nacional do Semiárido, Campina Grande, PB, Brazil

HIGHLIGHTS:

Estimates of leaf area of Congea tomentosa *based on measurements of leaf dimensions are a useful non-destructive method.*
Estimates of the leaf area of C. tomentosa *by statistical models are a non-expensive tool easily accessible to producers.*
The equation $\hat{y}$ = 0.63 × LW (Leaf: L = length, W = width) can be used to estimate the leaf area of C. tomentosa.

ABSTRACT: *Congea tomentosa* is a climbing plant suitable for covering arbors, railings, and fences. Leaf area determination is useful in understanding the plant-environment relationship and facilitating agronomic studies on transpiration, water requirement, light interception, and photosynthetic activity. The objective of this study was to obtain an allometric equation to estimate the leaf area of *C. tomentosa* by measuring the leaf dimensions. Analyses were performed on 200 leaves of different shapes and sizes from 10 randomly chosen adult plants grown under field conditions. The leaf length, leaf width, product length and width, and leaf area were determined. Linear, linear without intercept, quadratic, cubic, power, and exponential regression models were used to estimate the leaf area. The coefficient of determination, Willmott's concordance index, Akaike information criterion, root mean square error and BIAS index were used to determine the best model. The leaf area of *C. tomentosa* can be satisfactorily estimated using a non-destructive method that uses measurements of leaf dimensions. The equation $\hat{y}$ = 0.63 × LW (Leaf: L = length, W = width) estimates the leaf area of *C. tomentosa* in a practical and fast way, with 99.15% of precision. Estimation of the leaf area of *C. tomentosa* using statistical models is less expensive and easily accessible to researchers and producers of this plant.

Key words: leaf dimensions, vine, statistical models, modeling

RESUMO: *Congea tomentosa* é uma trepadeira indicada para cobertura de mandris, grades e cercas. A determinação da área foliar é útil para entender a relação planta-ambiente e facilitar estudos agronômicos sobre transpiração, necessidade de água, interceptação de luz e atividade fotossintética. O objetivo deste estudo foi obter uma equação alométrica para estimar a área foliar de *C. tomentosa* através da medição das dimensões foliares. As análises foram realizadas em 200 folhas de diferentes formas e tamanhos de 10 plantas adultas escolhidas aleatoriamente cultivadas em condições de campo. O comprimento da folha, a largura da folha, o produto do comprimento pela largura e a área foliar foram determinados. Modelos de regressão linear, linear sem intercepto, quadrático, cúbico, potência e exponencial foram utilizados para estimar a área foliar. O coeficiente de determinação, índice de concordância de Willmott, critério de informação de Akaike, raiz do quadrado médio do erro e índice BIAS foram usados para determinar o melhor modelo. A área foliar de *C. tomentosa* pode ser satisfatoriamente estimada por meio de um método não destrutivo que utiliza medidas de dimensões foliares. A equação $\hat{y}$ = 0,63 × LW (Folha: L = comprimento, W = largura) estima a área foliar de *C. tomentosa* de forma prática e rápida, com 99,15% de precisão. A estimativa da área foliar de *C. tomentosa* utilizando modelos estatísticos é menos dispendiosa e de fácil acesso aos pesquisadores e produtores desta planta.

Palavras-chave: dimensões de folhas, planta trepadeira, modelos estatísticos, modelagem

• Ref. 261222 – Received 18 Feb, 2022
* Corresponding author - E-mail: iarley.toshik@gmail.com
• Accepted 03 Jun, 2022 • Published 13 Jun, 2022
Editors: Lauriane Almeida dos Anjos Soares & Carlos Alberto Vieira de Azevedo

This is an open-access article distributed under the Creative Commons Attribution 4.0 International License.

Introduction

Congea tomentosa (Verbenaceae) is a woody species and a perennial vine native to India and Malaysia. The leaves are 10 to 16 cm in length and arranged oppositely, with elliptical oval, tomentose, and cartaceous type characteristics, marked by veins on the adaxial surface (Silva et al., 2017). This plant is used in ornamental gardens, including arbors, railings, and fences, in full sun (Sartin et al., 2014) and is used for medicinal purposes by indigenous people (Faruque et al., 2019). Therefore, evaluating its growth, development, and reproduction is relevant, considering the scarcity of information about this plant and its importance in gardening.

Leaves are important for controlling photosynthesis, respiration, transpiration, and other physiological attributes related to different ecosystem processes (Wales et al., 2020). Leaf area directly influences the use of natural resources, such as water, nutrients, and light. Estimation of the leaf area of *C. tomentosa* is of great importance because the plant is cultivated mainly for its leaves. Leaf area can be measured using direct or indirect and destructive or non-destructive methods (Keramatlou et al., 2015). Successive evaluations of the same plant can be performed quickly and accurately using indirect and non-destructive methods with allometric equations based on the length and width of the leaf (Ribeiro et al., 2020; Silva et al., 2020). Knowledge of the leaf area of ornamental plants is necessary for planning the plant's acclimatization conditions because of its landscape uses (Toscano et al., 2019) and, at physiological levels, knowing the plant's growth potential. The objective of this study was to obtain an allometric equation to estimate the leaf area of *C. tomentosa* by measuring the leaf dimensions.

Material and Methods

The research was performed at the Teaching, Research, and Extension Unit (UEPE), Floricultura-Belvedere, Universidade Federal de Viçosa, Viçosa, Minas Gerais State, Brazil (20º 45' S, 42° 52', and altitude of 690 m). *Congea tomentosa* seedlings were produced in 10 L pots filled with soil and manure (2:1, v:v). The seedlings were transplanted to the soil and placed in a panel (1 × 2.4 m) after the formation of roots and leaves. The plants were grown for 12 months before leaf collection. Two hundred leaves of different shapes and sizes (with greater data variability) were randomly collected from 10 adult plants grown under field conditions in March 2021. Healthy leaves without symptoms of attack by pests, diseases, or the influence of abiotic factors were selected (Figure 1).

The maximum length (L) and maximum width (W) was measured from digitized images using a digital flatbed scanner (Epson Scan I365) with a known scale. The leaf area was measured with ImageJ® software (LA) (Ribeiro et al., 2018). In ImageJ, the images of the leaves were contrasted to facilitate the determination of the leaf area. Descriptive analysis was used to obtain the maximum and minimum values, mean, median, total amplitude, variance, standard deviation, standard error, and coefficient of variation from the length (L), width (W), product (LW), and digital leaf area (LA).

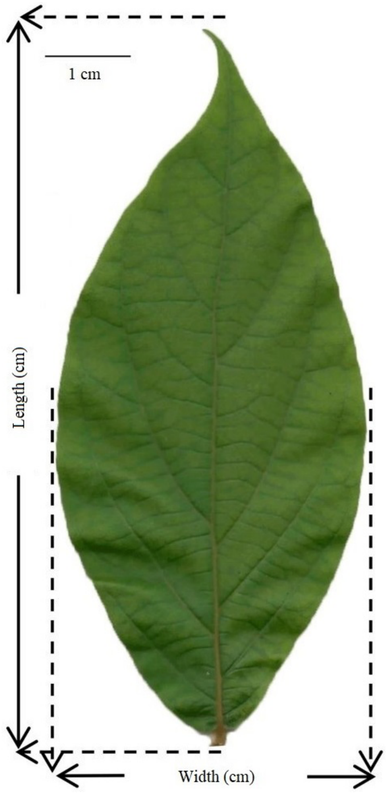


Figure 1. Maximum length (L) and width (W) of leaf of *Congea tomentosa* used to estimate leaf area

Regression analysis was used to obtain equations for calculating the leaf area of *C. tomentosa*. The following statistical equations were used for the analysis: linear, linear without intercept (0.0), quadratic, cubic, power, and exponential (Table 1).

The criteria of the highest coefficient of determination (R^2), Pearson's correlation coefficient (r), Willmott's agreement index (d) (Willmott,1981), lower Akaike information criterion (AIC) (Akaike, 1974), mean absolute error (MAE), root mean square error (RMSE) (Janssen & Heuberger, 1995), and BIAS index closest to zero (Leite & Andrade, 2002) were used to select the best equations. The statistical program R (R Core Team, 2021) was used to perform all analyses.

Table 1. Statistical models used to estimate the leaf area of *Congea tomentosa*

Model	Model description
Linear	$\hat{y} = \beta_0 + \beta_1{*}x + e_i$
Linear (0.0)	$\hat{y} = \beta_1{*}x + e_i$
Quadratic	$\hat{y} = \beta_0 + \beta_1{*}x + \beta_2{*}x^2 + e_i$
Cubic	$\hat{y} = \beta_0 + \beta_1{*}x + \beta_2{*}x^2 + \beta_3{*}x^3 + e_i$
Power	$\hat{y} = \beta_0{*}x^{\beta_1} + e_i$
Exponential	$\hat{y} = \beta_0{*}\beta_1^{x} + e_i$

* - Significant at $p \leq 0.05$ by F test
$\hat{y}$ - Leaf area; x - Leaf dimensios; β_0, β_1, β_2, β_3 - Model coefficients; e_i - Random error

Results and Discussion

The descriptive analysis of the data obtained from *C. tomentosa*, including the minimum, maximum, mean, median, variance, total amplitude, standard deviation, standard error, and coefficient of variation, is presented in Table 2.

Leaf length (L) varied from 6.56 to 17.77 cm, with an average of 12.28-11.20 cm in amplitude. The average leaf width was 5.48

Table 2. Minimum, maximum, mean, total amplitude, median, variance, standard deviation, standard error, and coefficient of variation (CV) for length (L), width (W), length by width (L.W) and digital leaf area (LA) of *Congea tomentosa* leaves

Descriptive statistic	L	W	LW	LA
	(cm)		(cm²)	
Minimum	6.56	2.28	14.94	9.79
Maximum	17.77	8.38	143.09	93.91
Mean	12.28	5.48	69.80	43.97
Total amplitude	11.20	6.11	128.15	84.13
Median	12.16	5.39	65.93	41.55
Variance	5.49	1.40	721.56	275.80
Standard deviation	2.34	1.18	26.86	16.61
Standard error	0.17	0.08	1.90	1.17
CV (%)	19.08	21.61	38.48	37.77

cm, with values ranging from 2.28 to 8.38 cm and 6.11 cm in amplitude. The length and width (LW) product ranged from 14.94 to 143.09 cm², with an average of 69.80 cm² and 128.15 cm in amplitude. The digital leaf area (LA) had an average of 43.97 cm², with a variation from 9.79 to 93.91 cm² and 84.13 in amplitude. Variation among the leaf dimensions is common in plants, especially those with a climbing habit. Climbing plants can adapt to diverse habitats (Fiorello et al., 2020). The statistical models used in this study have several advantages over destructive leaf area methods, as they are simple to use in field conditions and do not require plant destruction (Leite et al., 2019). The scatter plots between the pairs of variables L, W, and LA showed different relationships suggesting adjustments to linear and non-linear models (Figure 2).

The percentage distribution of the 200 leaves of *C. tomentosa* concerning size range was determined (Figure 3). The leaf area of more than 20% of the leaves varied between 36.51 to 45.50 cm². This factor is positive for this study because it has different leaf sizes, and the analyses have satisfactory accuracy and good data distribution (Shi et al., 2019).

Using simple linear measures to predict the leaf area of horticultural plants eliminates the need for expensive leaf area measurements (Hernández-Fernandéz et al., 2021). Small-scale farmers and researchers with limited financial resources could use this method. Regression models relating length (L), width (W), and their product (LW) to leaf area (LA) were evaluated (Table 3). The coefficient of determination for the linear models ranged from 0.8991 to 0.9978; quadratic models from 0.9115 to 0.9830; cubic models from 0.9130 to 0.9830, and power models from 0.9124 to 0.9832. The exponentials with smaller R^2 ranged from 0.8991 to 0.9348. Therefore, all the models estimated the leaf area of *C. tomentosa* with coefficients of determination (R^2) of 0.8991-0.9978. Such variations were reported for *Triticum aestivum* (Apolo-Apolo et al., 2020) and *Vitis vinifera* (Teobaldelli et al., 2020). The decision on which model to use depends mainly on the study's

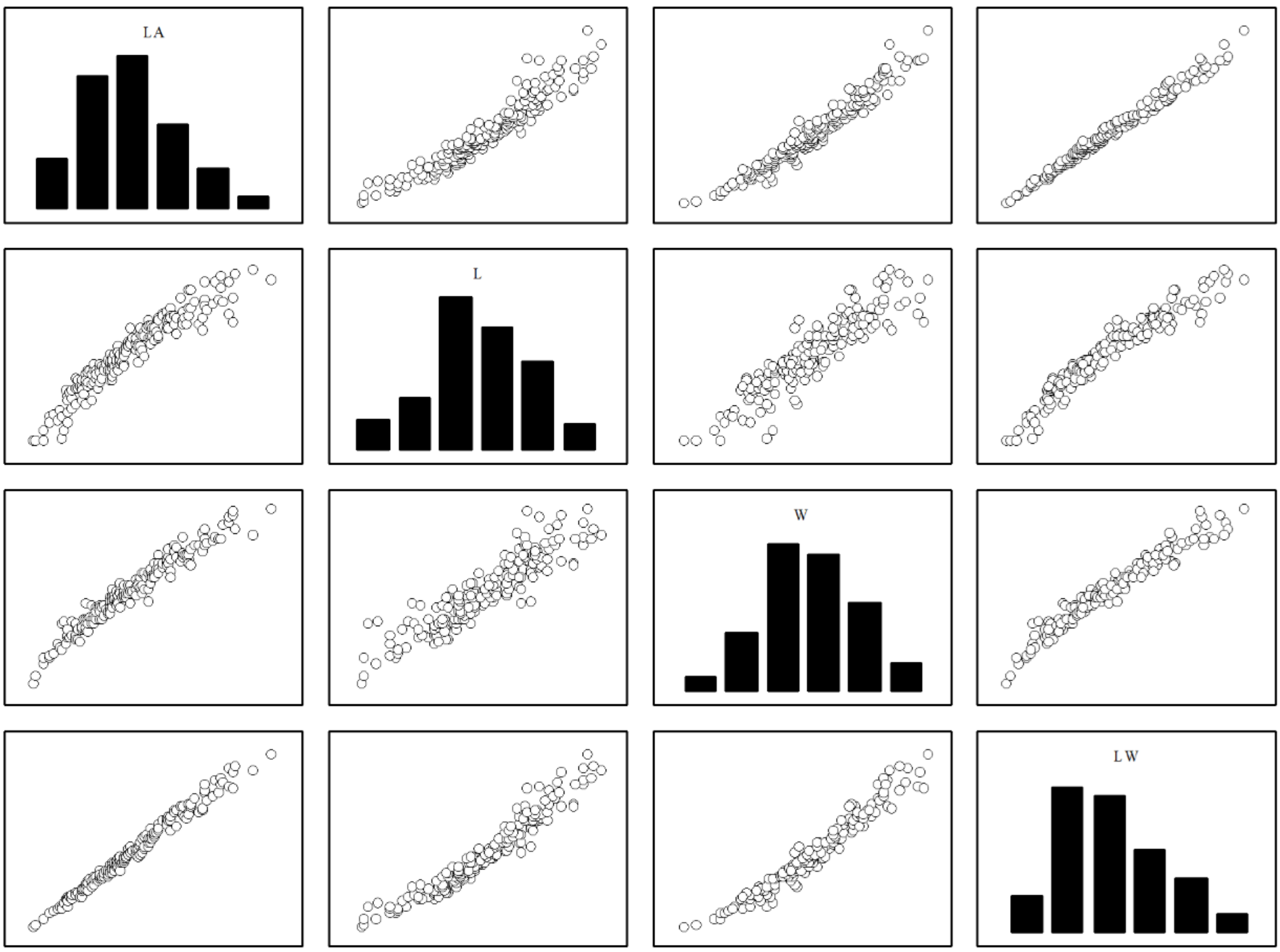


Figure 2. Histograms and model adjustments between leaf length (L), leaf width (W), product of length and width (LW) and digital leaf area (LA) of *Congea tomentosa* leaves

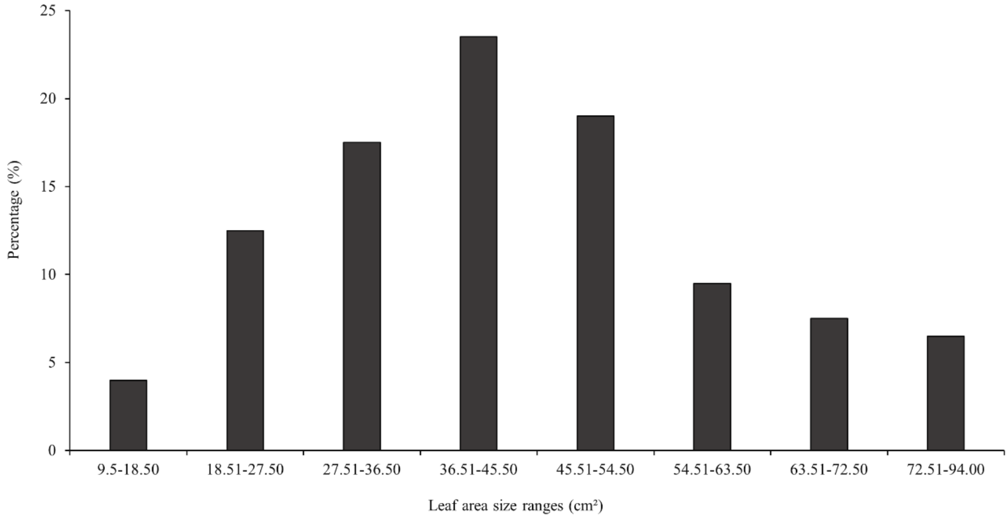


Figure 3. Percentage distribution of actual leaf area (LA) size classes of 200 leaves of *Congea tomentosa*

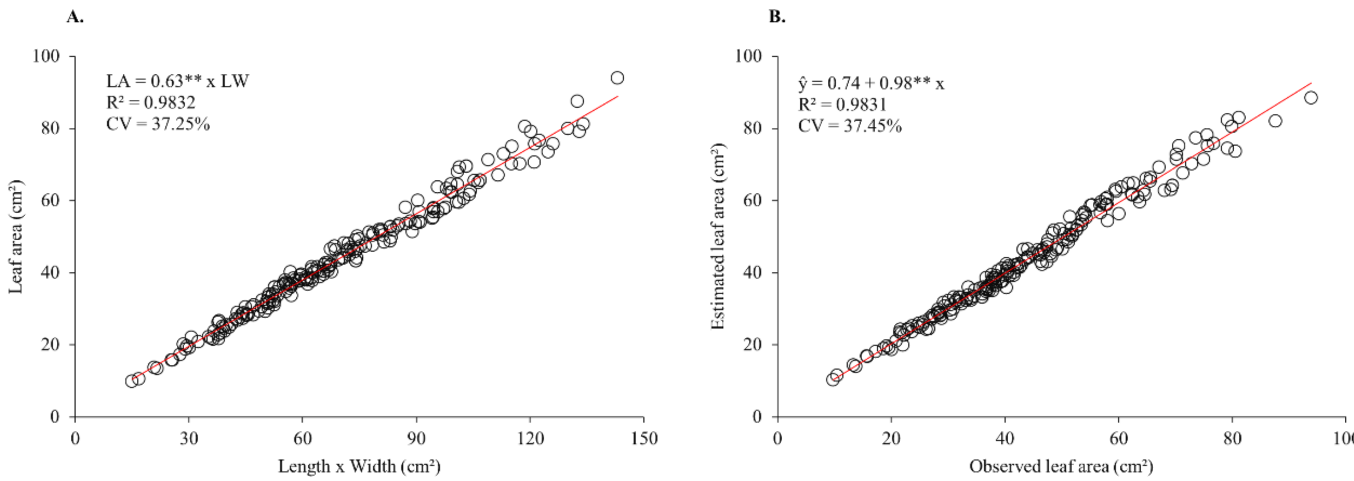
objective and the desired accuracy of the estimates (Teobaldelli et al., 2019).

The equation that satisfactorily estimated the leaf area of *C. tomentosa* as a function of leaf measurements was the linear model without the intercept using the product of length and width (LW), which had the highest R^2 value (0.9978) and d (0.9957), with low RMSE (2.1925) and AIC values (885.59) (Table 3). The equation $\hat{y} = 0.63 \times LW$ constructed from

Table 3. Equations, Pearson's correlation coefficient (r), coefficient of determination (R^2), Akaike information (AIC), root mean square error (RMSE), mean absolute error (MAE), and Willmott' agreement index (d), obtained as a function of measurements of dimensions of *Congea tomentosa* leaves

Model	x	r	R^2	AIC	RMSE	MAE	d	Equation	CV (%)
Linear	L	0.9485	0.8991	1236.86	5.2500	3.9781	0.9729	$\hat{y} = -38.59 + 6.72^{**} \times L$	36.76
Linear	W	0.9733	0.9471	1107.62	3.8004	2.8562	0.9863	$\hat{y} = -30.84 + 13.65^{**} \times W$	37.22
Linear	LW	0.9917	0.9832	880.02	2.1300	1.6525	0.9958	$\hat{y} = 1.18 + 0.61^{**} \times LW$	37.56
Linear (0.0)	LW	0.9915	0.9978	885.59	2.1925	1.7095	0.9957	$\hat{y} = 0.63^{**} \times LW$	37.25
Quadratic	L	0.9552	0.9115	1211.49	4.9027	3.6013	0.9766	$\hat{y} = -1.78 + 0.43^{ns} \times L + 0.26^{**} \times L^2$	36.88
Quadratic	W	0.9765	0.9530	1084.91	3.5728	2.6538	0.9880	$\hat{y} = -9.93 + 5.75^{**} \times W + 0.71^{**} \times W^2$	37.28
Quadratic	LW	0.9915	0.9830	881.91	2.1508	1.6754	0.9957	$\hat{y} = 0.89 + 0.62^{**} \times LW - 0.00005^{ns} \times LW^2$	37.56
Cubic	L	0.9562	0.9130	1209.07	4.8488	3.5910	0.9771	$\hat{y} = 48.44 - 13.06^{*} \times L + 1.42^{*} \times L^2 - 0.03^{*} \times L^3$	36.90
Cubic	W	0.9767	0.9532	1085.09	3.5565	2.6443	0.9881	$\hat{y} = 5.60 - 3.61^{ns} \times W + 2.51^{*} \times W^2 - 0.11^{ns} \times W^3$	37.28
Cubic	LW	0.9915	0.9830	880.01	2.1514	1.6815	0.9957	$\hat{y} = -2.3 + 0.78^{**} \times LW - 0.002^{*} \times LW^2 + 0.00001^{ns} \times LW^3$	37.56
Power	L	0.9552	0.9124	1209.43	4.9020	3.6008	0.9766	$\hat{y} = 0.31^{**} \times L^{1.96^{**}}$	36.85
Power	W	0.9763	0.9531	1084.58	3.5877	2.6734	0.9878	$\hat{y} = 2.26^{**} \times W^{1.73^{**}}$	37.16
Power	LW	0.9915	0.9832	879.64	2.1494	1.6662	0.9957	$\hat{y} = 0.71^{**} \times LW^{0.97^{**}}$	37.56
Exponential	L	0.9482	0.8991	1239.13	5.2798	3.8593	0.9719	$\hat{y} = 6.74^{**} \times 1.16^{**L}$	36.25
Exponential	W	0.9668	0.9348	1153.10	4.2581	3.2546	0.9822	$\hat{y} = 8.59^{**} \times 1.33^{**W}$	36.53
Exponential	LW	0.9668	0.9348	1116.72	4.2581	3.2546	0.9822	$\hat{y} = 17.89^{**} \times 1.01^{**LW}$	36.56

x - Measurements of leaf dimensions; $\hat{y}$ – Estimated leaf area (LA). **, *, ^{ns} - Significant at $p \leq 0.01$, 0.05 and not significant, respectively, by F test; CV - Coefficient of variation



** - Significant at $p \leq 0.01$ by F test

Figure 4. Relationship between digital leaf area (LA) and length × width (LW) (A) and relationship between estimated digital leaf area and observed digital leaf area (B)

this model is the most suitable to estimate the leaf area of *C. tomentosa*. Similar results were obtained in studies on *Tectona grandis* (Silva et al., 2020), *Theobroma cacao* (Schmildt et al., 2017), *Manihot* sp. (Leite et al., 2021), *Erythrina velutina* (Ribeiro et al., 2022), *Juglans regia* (Keramatlou et al., 2015), *Talinum triangulare*, *Talinum paniculatum* (Oliveira et al., 2019) and *Eustoma grandiflorum* (Dias et al., 2022). By estimating the leaf area using non-destructive models, it is possible to explain plants' agronomic and physiological behavior concerning the availability of radiation and water (Salazar et al., 2018).

The relationship between the digital leaf area and length × width (Figure 4A) and the estimated and observed digital leaf area (Figure 4B) was evaluated. The coefficient of determination (R^2) is almost similar (0.9832 and 0.9831), suggesting that the data dispersions were minimal with the objective line, indicating that the linear model with the intercept satisfactorily describes the leaf area (Oliveira et al., 2019).

Leaf area estimation by non-destructive methods is used widely in studies of photosynthetic capacity, fertilization levels, and water availability, among others (Suárez et al., 2022), and is an excellent low-cost tool for use in field crops.

Conclusions

1. The leaf area of *C. tomentosa* can be estimated reasonably with a non-destructive method, which uses measurements of leaf dimensions.

2. The equation $\hat{y} = 0.63 \times LW$ (where L and W are, respectively, the length and width of the leaf) estimates the leaf area of *C. tomentosa* in a practical and fast way, with a correlation coefficient of 0.9915.

3. The estimation of the leaf area of *C. tomentosa* by statistical models is less expensive and easily accessible to researchers and producers of this plant.

Acknowledgments

The authors thanks to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) (financial code 001) and to the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) for the scholarships awarded to authors.

Literature Cited

Akaike, H. A new look at the statistical model identification. IEEE Transactions on Automatic Control, v.19, p.716-723, 1974. https://doi.org/10.1109/TAC.1974.1100705

Apolo-Apolo, O. E.; Pérez-Ruiz, M.; Martínez-Guanter, J.; Egea, G. A mixed databased deep neural network to estimate leaf area index in wheat breeding trials. Agronomy, v.10, p.1-21, 2020. https://doi.org/10.3390/agronomy10020175

Dias, M. G.; Silva, T. I. da; Ribeiro, J. E. da S.; Grossi, J. A. S.; Barbosa, J. G. Allometric models for estimating the leaf area of lisianthus (*Eustoma grandiflorum*) using a non-destructive method. Revista Ceres, v.69, p.7-12, 2022. https://doi.org/10.1590/0034-737X202269010002

Faruque, M. O.; Ankhi, U. R.; Kamaruzzaman, M.; Barlow, J. W.; Zhou, B.; Hao, J.; Hu, X. Chemical composition and antimicrobial activity of *Congea tomentosa*, an ethnomedicinal plant from Bangladesh. Industrial Crops and Products, v.141, p.1-10, 2019. https://doi.org/10.1016/j.indcrop.2019.111745

Fiorello, I.; Tricinci, O.; Naselli, G. A.; Mondini, A.; Filippeschi, C.; Tramacere, F.; Mishra, A. K.; Mazzolai, B. Climbing plant-inspired micropatterned devices for reversible attachment. Advanced Functional Materials, v.30, p.1-11, 2020. https://doi.org/10.1002/adfm.202003380

Hernández-Fernandéz, I. A.; Jarma-Orozco, A.; Pompelli, M. F. Allometric models for non-destructive leaf area measurement of stevia: an in depth and complete analysis. Horticultura Brasileira, v.39, p.205-215, 2021. https://doi.org/10.1590/s0102-0536-20210212

Janssen, P. H. M.; Heuberger P. S. C. Calibration of process - oriented models. Ecological Modelling, v.83, p.55-56, 1995. https://doi.org/10.1016/0304-3800(95)00084-9

Keramatlou, I.; Sharifani, M.; Sabouri, H.; Alizadeh, M.; Kamkar, B. A simple linear model for leaf area estimation in Persian walnut (*Juglans regia* L.). Scientia Horticulturae, v.184, p.36-39, 2015. https://doi.org/10.1016/j.scienta.2014.12.017

Leite, H. G.; Andrade, V. C. L. de. Um método para condução de inventários florestais sem o uso de equações volumétricas. Revista Árvore, v.26, p.321-328, 2002. https://doi.org/10.1590/S0100-67622002000300007

Leite, M. L. de M. V.; Lucena, L. R. R. de; Cruz, M. G. da; Sá Junior, E. H. de; Simões, V. J. L. P. Leaf area estimate of *Pennisetum glaucum* by linear dimensions. Acta Scientiarum: Animal Sciences, v.41, p.1-7, 2019. http://dx.doi.org/10.4025/actascianimsci.v41i1.42808

Leite, M. L. de M. V.; Moura, G. A. de; Moura, E. A. de; Lucena, L. R. R. de; Sales, A. T.; Sampaio, E. V. de S. B. Comparison of methods for estimating leaf area in pornunça (*Manihot* sp.). Revista Brasileira de Engenharia Agrícola e Ambiental, v.25, p.733-740, 2021. https://doi.org/10.1590/1807-1929/agriambi.v25n11p733-740

Oliveira, R. F.; Jakelaitis, A.; Alexandre, E. C. F.; Pereira, L. S.; Silva, M. N. da; Oliveira, D. E. C. de; Sousa, G. D. de; Oliveira, G. S. de. Utilização de modelos alométricos para estimar a área foliar de *Talinum triangulare* e *Talinum paniculatum*. Revista Brasileira de Agropecuária Sustentável, v.9, p.112-119, 2019.

R Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, 2021.

Ribeiro, J. E. da S.; Barbosa, A. J. S.; Albuquerque, M. B. de. Leaf area estimate of *Erythroxylum simonis* Plowman by linear dimensions. Floresta e Ambiente, v.25, p.1-7, 2018. https://doi.org/10.1590/2179-8087.010817

Ribeiro, J. E. da S.; Figueiredo, F. R. A.; Nóbrega, J. S.; Coêlho, E. dos S.; Melo, M. F. Leaf area of *Erythrina velutina* Willd. (Fabaceae) through allometric equations. Revista Floresta, v.52, p.93-102, 2022. http://dx.doi.org/10.5380/rf.v52i1.78059

Ribeiro, J. E. da S.; Nóbrega, J. S.; Figueiredo, F. R. A.; Ferreira, J. T. A.; Pereira, W. E.; Bruno, R. de L. A.; Albuquerque, M. B. de. Estimativa da área foliar de *Mesosphaerum suaveolens* a partir de relações alométricas. Rodriguésia, v.71, p.1-9, 2020. https://doi.org/10.1590/2175-7860202071115

Salazar, J. C. S.; Melgarejo, L. M.; Bautista, E. H. D.; Di Rienzo, J. A.; Casanoves, F. Non-destructive estimation of the leaf weight and leaf area in cacao (*Theobroma cacao* L.). Scientia Horticulturae, v.229, p.19-24, 2018. https://doi.org/10.1016/j.scienta.2017.10.034

Sartin, R. D.; Peixoto, J. de C.; Lopes, D. B.; Paula, J. R. de. Flora do Bioma Cerrado: Abordagem de estudos da família Acanthaceae Juss – espécies ornamentais no Brasil. Fronteiras, v.3, p.164-179, 2014. https://doi.org/10.21664/2238-8869.2014v3i2.p164-179

Schmildt, E. R.; Trevisan, E.; Belique, M.; Schmildt, O. Modelos alométricos para determinação da área foliar de cacaueiro 'PH-16' em sombreamento e pleno sol. Revista Agro@mbiente, v.11, p.47-55, 2017. http://dx.doi.org/10.18227/1982-8470ragro.v11i1.3938

Shi, P.; Liu, M.; Yu, X.; Gielis, J.; Ratkowsky, D. A. Proportional relationship between leaf area and the product of leaf length and width of four types of special leaf shapes. Forests, v.10, p.1-13, 2019. https://doi.org/10.3390/f10020178

Silva, C. C. da; Souza, A. P.; Bouvié, L.; Ferneda, B. G.; Leite Neto, A.; Monteiro, E. B. Modelos alométricos para estimar a área do limbo foliar de teca. Nativa, v.8, p.129-136, 2020. http://orcid.org/0000-0002-1079-8728

Silva, G. P. V. da; Possamai, B. T.; Schroeder, G. da R.; Vieira Junior, N. P.; Dec, E.; Mouga, D. M. D. da S. Palynological characterization of species of Verbenaceae J. St.-Hil. and Lamiaceae Martinov (Lamiales Bromhead). Acta Biológica Catarinense, v.4, p.68-76, 2017.

Suárez, J. C.; Casanoves, F.; Di Rienzo, J. Non-Destructive estimation of the leaf weight and leaf area in common bean. Agronomy, v.12, p.1-14, 2022. https://doi.org/10.3390/agronomy12030711

Teobaldelli, M.; Rouphael, Y.; Fascella, G.; Cristofori, V.; Rivera, C. M.; Basile, B. Developing an accurate and fast non-destructive single leaf area model for loquat (*Eriobotrya japonica* Lindl) cultivars. Plants, v.8, p.1-12, 2019. http://dx.doi.org/10.3390/plants8070230

Teobaldelli, M.; Rouphael, Y.; Gonnella, M.; Buttaro, D.; Rivera, C. M.; Muganu, M.; Basile, B. Developing a fast and accurate model to estimate allometrically the total shoot leaf area in grapevines. Scientia Horticulturae, v.259, p.1-9, 2020. https://doi.org/10.1016/j.scienta.2019.108794

Toscano, S.; Ferrante, A.; Romano, D. Response of Mediterranean ornamental plants to drought stress. Horticulturae, v.51, p.1-20, 2019. https://doi.org/10.3390/horticulturae5010006

Wales, S. B.; Kreider, M. R.; Atkins, J.; Hulshof, C. M.; Fahey, R. T.; Nave, L. E.; Nadelhoffer, K. J.; Gough, C. M. Stand age, disturbance history and the temporal stability of forest production. Forest Ecology and Management, v.460, p.1-9, 2020. https://doi.org/10.1016/j.foreco.2020.117865

Willmott, C. J. On the validation of models. Physical Geography, v.2, p.184-194, 1981. https://doi.org/10.1080/02723646.1981.10642213