Crown projection area of *Licania tomentosa* (Benth.) Fritsch (Chrysobalanaceae), estimated by linear regression

Área de projeção da copa de *Licania tomentosa* (Benth.) Fritsch (Chrysobalanaceae), estimada por regressão linear

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ABSTRACT
Knowledge of the Crown Projection Area (CPA) allows to make inferences about the shading and to know space occupied by a tree. However, crown measurements are more time-consuming and laborious when compared to those of Circumference Breast Height (CBH). Thus, this work aimed to evaluate regression models and present the most suitable to CPA estimate of *Licania tomentosa*, in an urban area of São João Evangelista municipality, Brazil. Fifty trees distributed over 7 public roads were sampled. CBH and Crown Diameter (CD, m) were measured for later calculation of its projection area (CPA, m^2). Four regression models were tested in order to estimate CPA as a function of CBH alone. The equation derived from of the model "$CPA = \beta_0 + \beta_1 CBH + \varepsilon$" showed a homoscedastic distribution of the percentage residues, with closer deviations around the abscissa axis. It is concluded that the equation obtained with the adjustment of the simple linear model was the most efficient to estimate of the crown projection area of *L. tomentosa*. This projection area increased as the stem of the trees thickened.

Keywords: afforestation, oiti, regression, shading

RESUMO
O conhecimento da Área de Projeção da Copa (APC) permite realizar inferências sobre o sombreamento e conhecer o espaço ocupado por uma árvore. Entretanto, medições de copa são mais demoradas e laboriosas quando comparadas com as de Circunferência à Altura do Peito (CAP). Deste modo, os objetivos foram avaliar modelos de regressão e apresentar o mais indicado para estimar a APC de *Licania tomentosa*, em área urbana do município de São João Evangelista – MG. Foram amostradas 50 árvores distribuídas em 7 vias públicas. Mensuraram-se a CAP e o Diâmetro da Copa (DC, m), para posterior cálculo de sua área de projeção (APC, m^2). Foram testados quatro modelos de regressão a fim de estimar a APC em função apenas do CAP. A equação proveniente do ajuste do modelo "$APC = \beta_0 + \beta_1 CAP + \varepsilon$" apresentou distribuição homocedástica dos resíduos percentuais, com desvios mais próximos em torno do eixo das abcissas. Conclui-se que a equação obtida com o ajuste do modelo linear simples foi a mais eficiente para estimar a área de projeção da copa *L. tomentosa*. Esta área de projeção aumentou à medida que engrossou o fuste das árvores.

Palavras-chave: arborização, oiti, regressão, sombreamento

1 INTRODUCTION

Licania tomentosa (Benth.) Fritsch. (Chrysobalanaceae), popularly known as oiti or Octizeiro, is a tree species native of the Atlantic Forest, with heliophile, perennial and fruit characteristics (ZAMPRONI et al., 2016). Because it has a leafy crown and provides shade, it is preferred for planting in squares, gardens, streets and avenues. The wood of the species is heavy, resistant and of long durability, used for energy and crafts.

The trees presence in landscape promotes scenic beauty, improving aesthetics mainly during the flowering season (LAFETÁ et al., 2020; LAFETÁ et al., 2021). Urban afforestation on public roads is essential for maintaining life quality, mitigating pollution effects, providing shade, leisure, shelter and food for local fauna. However, the lack of available data on urban afforestation is a reality in Brazil (ANGEOLETTON et al., 2018).

The importance of urban ecological services has been highlighted due to population growth, expansion of urban areas (SANESI et al., 2016; SARTORI et al., 2019; SHODA et al., 2020) and recent research on the trees valuation (JONES et al. 2018). Afforestation is even an indication of population's financial quality; neighborhoods whose residents show more financial income tend to be more wooded (ANGEOLETTO et al., 2017; ANGEOLETTON et al., 2018). It should be noted that urban expansions occur mainly due to housing construction in inadequate land use conditions (SARTORI et al., 2019).

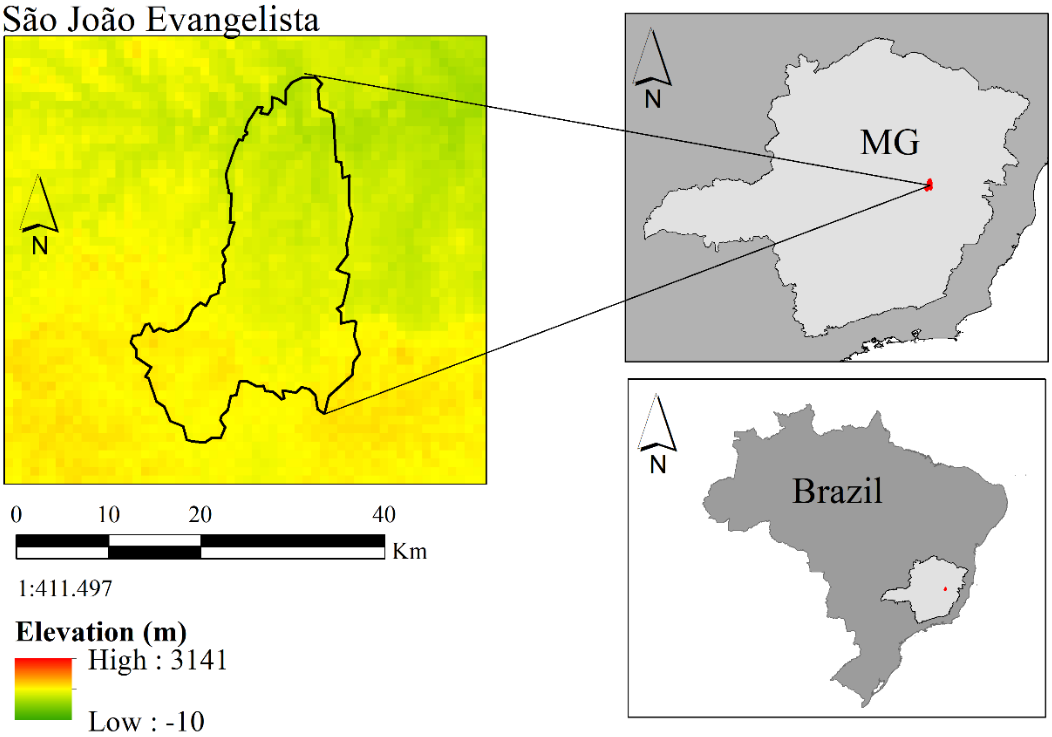
Crown projection area, in turn, is a measure of the surface covered by its vertical projection and allows to know the space occupied by a tree (FERREIRA et al., 2015). Usually, it is calculated from a set of measurements of the crown projection rays (around four to eight rays) (DURLO and DENARDI, 1998).

Regression modeling emerges as an alternative to support decision making on the design of urban green space. Thus, this work aimed to evaluate regression models and present the most suitable to estimate of the crown projection area of *L. tomentosa*, in urban area of São João Evangelista municipality, Brazil.

2 MATERIAL AND METHODS

The work was carried out in São João Evangelista municipality, inserted in the Vale do Rio Doce – Minas Gerais, Brazil (Figure 1). Region climate is Cwa type (temperate rainy-mesothermal) according to the international classification of Köppen system. Altitude in the city center is 680m and annual averages of temperature and precipitation are 19.1°C and 1.360 mm (INMET, 2018), respectively.

Figure 1 – Location of São João Evangelista municipality, inserted in the Vale do Rio Doce - Minas Gerais, Brazil.



Fifty trees of the species *L. tomentosa* were sampled distributed in 7 public roads. The trees had a slender crown and no apparent signs of pruning, injury or insect attack; average height was 7.85 ± 1.21 m. The circumference was measured at 1.30 m above the ground (Circumference Breast Height, CBH, cm) of all trees with the aid of a tape measure. Crown Diameter (CD, m) was represented by the average of two diameters, obtained by measuring four rays in the directions parallel (//) and perpendicular (⊥) to the orientation of public roads through crown vertical projection. Crown Projection Area (CPA, m^2) was calculated using the equation "$CPA = DC^2.\pi/4$".

Four regression models were tested to estimate CPA as a function of CBH alone (Table 1). In the regression analysis, Ordinary Least Squares (OLS) method was used. CBH was chosen as a variable independent from the models because it is considered an attribute that is easy to measure in field. Residues normality was assessed by the Shapiro-Wilk test, variance homoscedasticity by Breusch-Pagan and autocorrelation by Durbin-Watson. In order to assess multicollinearity presence in the model (2), Variance Inflation value (VIF) was calculated.

Table 1 - Models tested to estimate Crown Projection Area (CPA) of *Licania tomentosa*, in urban area of the São João Evangelista municipality – Minas Gerais, Brazil.

Model	Fit form	Functional form
(1)	$CPA = \beta_0 + \beta_1 CBH + \varepsilon$	$\widehat{CPA} = \beta_0 + \beta_1 CBH$
(2)	$CPA = \beta_0 + \beta_1 CBH + \beta_2 CBH^2 + \varepsilon$	$\widehat{CPA} = \beta_0 + \beta_1 CBH + \beta_2 CBH^2$
(3)	$CPA = \beta_0 + \beta_1 (1/CBH) + \varepsilon$	$\widehat{CPA} = \beta_0 + \beta_1 (1/CBH)$
(4)	$Ln\ CPA = \beta_0 + \beta_1\ Ln\ CBH + \varepsilon$	$\widehat{CPA} = e^{\beta_0 + \beta_1\ Ln\ CBH}$

β_0, β_1 and β_2 = parameters of the regression models and ε = random error.

Adjustments quality was assessed according to the parameters significance by the t-test and Pearson's correlation coefficient values ($r_{Y\hat{Y}}$), adjusted determination coefficient ($\bar{R}^2$), Root Mean Squared Error (RMSE) and Akaike information criteria (AIC). Equations adherence to the data was assessed by Kolmogorov-Smirnov test. The best predictive performance equation was selected for subsequent graphical analyzes.

Statistical analyzes were performed with the aid of the software R 3.3 (R CORE TEAM, 2017) and Excel®, adopting a significance level of 5% probability.

3 RESULTS AND DISCUSSIONS

Normality and variances homoscedasticity were verified in all adjustments. Only adjustment made for the model (4) showed autocorrelation by the Durbin-Watson test, being disregarded in subsequent graphic analyzes. It should be noted that the autocorrelation absence is a fundamental premise for OLS method to provide reliable and unbiased estimates (GUJARATI, 2000). Parameters and adjustments quality are shown in Table 2.

Table 2 - Parameters and adjustments quality of the regression models tested to estimate crown projection area of *Licania tomentosa*, in an urban area of São João Evangelista municipality – Minas Gerais, Brazil.

Attributes	Model (1)	Model (2)	Model (3)	Model (4)
β_0	-24,2994*	-21,8475^{ns}	147,4200*	-2,8942*
β_1	0,6904*	0,6530^{ns}	-9961,5100*	1,4391*
β_2	-	0,0001^{ns}	-	-
$r_{Y\hat{Y}}$	0,7718*	0,7718*	0,7192*	0,7704*
$\bar{R}^2$	0,5872	0,5785	0,5072	0,5378
RMSE	19,3915	19,3902	21,1870	19,6918
AIC	444	446	453	41

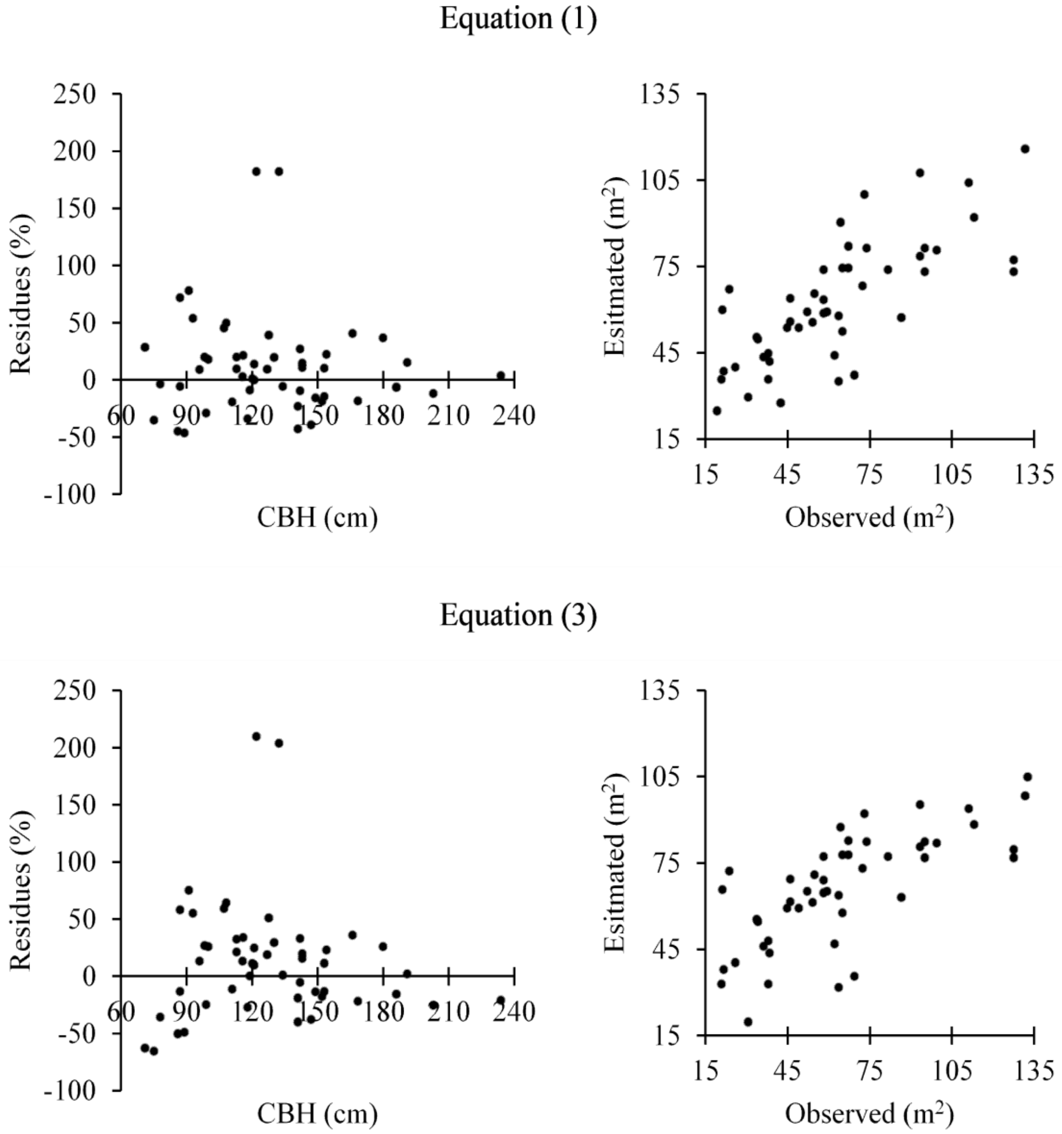
*, ns significant and non-significant at 5% probability. β_0, β_1 and β_2 = parameters of regression models; $r_{Y\hat{Y}}$ = correlation coefficient; $\bar{R}^2$ = adjusted coefficient of determination; RMSE = root mean squared error; and AIC = Akaike's information criterion.

Model (2) parameters were not significant by the t-test, presenting an adjusted coefficient of determination close to that of the other adjustments. Variance inflation value of the model (2) was above 10 (VIF = 34), a clear indication of multicollinearity (GUJARATI, 2000). In these circumstances, regression parameter fails to reflect inherent effects of a particular independent variable on that dependent one, partially reflecting its real effect. It is likely that multicollinearity was a consequence of the high correlation ($r_{Y\hat{Y}}$ = 0.9853, p ≤ 0.05) between independent variables of the model (2). Therefore, this model was also disregarded in the other graphic analyzes.

Significant regression of the models (1) and (3) demonstrated that generated equations can explain high proportions of the CBH variability; variation amplitude found for CAP was 71 to 234 cm. Equations adherence to the observed data was verified in the adjustment of both models, showing potential to describe relationship between CBH and the CPA.

Graphical analysis (Figure 2) confirmed homoscedasticity of the equations obtained with adjustment of models (1) and (3). However, there was a loss of precision in equation (3), underestimating APC of the thinnest and largest CAP trees. The predictive superiority of equation (1) was found, with higher values of $r_{Y\hat{Y}}$ and $\bar{R}^2$, and in relation to equation (3), lower RMSE and AIC. Trees with thicker stems of *L. tomentosa* provided greater shading, with a direct linear relationship between CPA and CBH.

Figure 2. Graphical representation of percentage residual distribution of the equations selected to estimate *Licania tomentosa* Crown Projection Area (APC) and CPA estimated vs. CPA observed.



Planning of urban areas afforestation with use of *L. tomentosa* should be viewed with caution, if possible, assigning species to areas with large non-waterproofed space, such as squares, gardens and central flowerbeds. Some care should be taken when choosing planting location, since, depending on the edaphic and climatic conditions, crown may present dimensions capable of compromising the electrical wiring and making it difficult for passers-by to pass. As long as carried out by qualified professionals, pruning is a viable alternative to properly conduct trees growth on sidewalks and other environments with restricted physical space.

4 CONCLUSIONS

The equation obtained with adjustment of the simple linear model is efficient to estimate projection area of *Licania tomentosa* crown.

The crown projection area of *Licania tomentosa* increases linearly with the circumference breast height of the tree.

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