Note

ESTIMATING THE TOTAL LEAF AREA OF THE GREEN DWARF COCONUT TREE (*Cocos nucifera* L.)

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ABSTRACT: Leaf area has significant effect on tree transpiration, and its measurement is important to many study areas. This work aimed at developing a non-destructive, practical, and empirical method to estimate the total leaf area of green dwarf coconut palms (*Cocos nucifera* L.) in plantations located at the northern region of Rio de Janeiro state, Brazil. A mathematical model was developed to estimate total leaf area values (TLA) as function of the average lengths of the last three leaf raquis (LR3), and of the number of leaves in the canopy (NL). The model has satisfactory degree of accuracy for agricultural engineering purposes.
Key words: canopy structure, mathematic model, estimating model

ESTIMAÇÃO DA ÁREA FOLIAR TOTAL DO COQUEIRO ANÃO VERDE (*Cocos nucifera* L.)

RESUMO: A área foliar influencia a transpiração de uma árvore e sua determinação é importante para diversos ramos da ciência. Este trabalho teve como objetivo desenvolver um modelo matemático empírico prático não-destrutivo para estimar a área foliar total do coqueiro anão verde (*Cocos nucifera* L.) na região Norte Fluminense. Com o modelo desenvolvido pôde-se estimar o valor da área foliar total (TLA) em função da média dos comprimentos das três ultimas raques foliares (LR3) e do número de folhas na copa da cultura (NL). O modelo obtido é satisfatoriamente acurado para estimar a TLA do coqueiro anão verde.
Palavras-chave: estrutura do dossel, modelo matemático, modelo de estimação

INTRODUCTION

Transpiration rates of trees depend on the conjugation of environmental and biological factors (Pereira et al., 1997). The leaf area, the canopy architecture and the planting disposition are biological factors that determine the light interception and, therefore, the efficiency of the photosynthetic and transpiration rate (Pereira et al., 1997; Nobel, 1991; Taiz & Zeiger, 1991). Thus, the knowledge of the plant leaf area is important for the evaluation and understanding of the vegetative growth and water loss by the plant (Norman & Campbell, 1989).

The total leaf area of the plant can be obtained by either direct or indirect methods. The direct method consists of removing and measuring all leaves in the plant. This method is destructive and requires adequate, potentially expensive equipment. Indirect, nondestructive methods are user friendly, less expensive, and can providing accurate leaf area estimates (Norman & Campbell, 1989).

Various mathematical models for indirect estimation of leaf area of several tropical plants have been described (Gonçalves et al., 2002; Campostrini & Yamanishi, 2001; Panta & NeSmith, 1995; Gamiely et al., 1991; NeSmith, 1991; Robbins & Pharr, 1987; Pereira & Splittstoesser, 1986; Rao et al., 1978). This is not true regarding dwarf coconut trees. The objective of this work was thus to developing a nondestructive, empirical model to estimate leaf area of green dwarf coconut with the number of variables kept to a minimum, facilitating data collection and making it useful to a wider extent of users, such as agricultural technicians and farmers.

MATERIAL AND METHODS

This study was carried out at two stages. First, an empirical model for leaf area of individual leaves of green dwarf coconut tree was developed and evaluated. A sample of 57 leaves was collected in a intermediate position on the canopy, at an irrigated orchard located at Campos dos Goytacazes, RJ, Brazil (21°48'2" S, 41°10'51" W).

In each leaf, the length of the rachis (LR) was measured, and the sum of all leaflet areas (LA) was determined through leaf area meter (LI-3100 area meter, LI-COR Inc., Lincoln, Nebraska, USA). The length of the rachis in the collected leaves ranged from 0.48 m to 3.3 m; age of plants varied from one to four years. The model for leaf area (Equation 1) was developed using linear regression on anamorphosis scheme, using leaf rachis length as independent variable.

$$LA = a\,[LR]^{b} \quad (1)$$

where: LA = estimated area of one leaf (m^2); LR = length of the leaf rachis (m); and a, b = fitted regression coefficients.

The potential model was chosen for its simplicity, producing results with the same level of accuracy as other more complex estimation models. To validate the model, the same previous measures were taken in 31 plant leaves of other croppings located at four differents areas (L1 up to L4) in Campos dos Goytacazes County, RJ, Brazil (L1: 21°45'43" S, 41°17'27" W; L2: 21°45'0" S, 41°18'27" W; L3: 21°43'24" S, 41°20'53" W; L4: 21°48'2" S, 41°10'51" W). Trees evaluated in areas L1 and L2 were not irrigated, and their average ages were two and ten years, respectively; in L3 trees were one to three years old; in L4, the trees were 2.5 to 4.5 years old. Both L3 and L4 were regularly irrigated.

After defining the mathematical model (Equation 1), the total leaf area could be estimated by measuring the length of all rachis and summing all the estimated leaf areas. However, this procedure is difficult in some situations, especially when trying to measure lengths of the flag leaf rachis in more developed trees.

In the second stage of this work, a model for estimating total leaf area of each tree was developed, using trees randomly selected in the orchards. Twenty five plants were used for developing the model, and 21 were used for validating the model.

In each tree, the length of the rachis in all canopy leaves (except the flag leaf) was measured and the average rachis length (ARL) calculated. Applying the leaf-area estimation model (Equation 1), the total leaf area of each tree was determined, by summing the areas of all leaves. The number of leaves on a tree was counted (NL) and the average rachis lengths of the last three leaves (LR3) were measured. The flag leaf was the zero leaf. The NF ranged from seven to 24.

Through multiple linear regression, an empirical model was fitted to estimate the ARL, as a function of LR3 and NF (Equation 2).

$$ARL = a_1 + b_1[LR3] + c_1[LR3]^2 + d_1[NL] \quad (2)$$

where: ARL = average rachis length of the coconut tree canopy (m); a_1, b_1, c_1, d_1 = fitted regression coefficients.

The total leaf area of each tree (TLA, m^2), was then estimated by:

$$TLA = \{a\,[ARL]^{b}\}NL \quad (3)$$

The proposed models were validated by fitting the simple linear regression model of the predicted values (dependent variable) to the respective observed values (independent variable). Statistical analyses were conducted under the following hypotheses:

$$\begin{cases} H_0: b_0 = 0 \\ H_a: b_0 \neq 0 \end{cases} \qquad \begin{cases} H_0: b_1 = 1 \\ H_a: b_1 \neq 1 \end{cases} \quad (4)$$

where: b_o is the y-axis intercept, and b_1 represents the slope of the best fit linear model obtained through regression analysis, using experimental and observed values.

In relation to the no-rejection case of both nullity hypotheses, it was concluded by the equivalence between the predicted and the observed values. A value of 0.05 was adopted as the critical probability level for the occurrence of the type-I error.

RESULTS AND DISCUSSION

The regression for single leaf area as a function of leaf rachis length realistically describes the single leaf area (Figure 1). The fitted model (Equation 5) had $r^2 = 0.95$ ($P < 0.01$).

$$LA = 0.8282\,[LR]^{1.5662} \quad (5)$$

Validation of this model with independent data from L1 to L4 showed strong correlation and no consistent bias (Figure 2). The linear regression analysis had intercept not different from zero, and slope not different from 1.0 ($P > 0.05$). These results show the viability of estimating the coconut tree leaf area using a simple measure of the leaf rachis length.

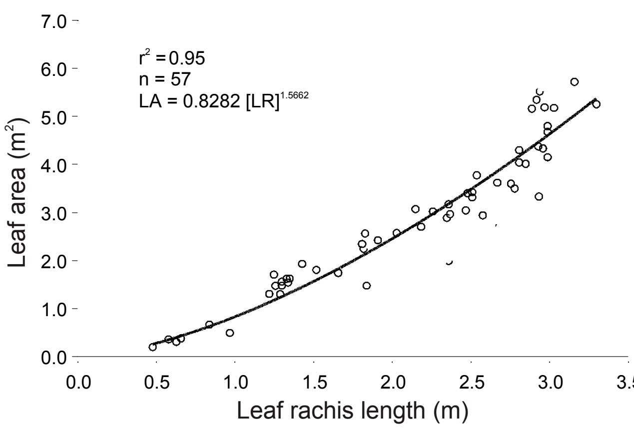

Figure 1 - Relationship between the leaf rachis length (LR) and the leaf area (LA) in the green dwarf coconut tree.

The model for estimating the ARL from LR3 and NL was:

$$ARL = - 0.3125 + 1.3207\ [LR3] - 0.2078\ [LR3]^2 + 0.05407\ [NL] \quad (6)$$

The observed values of the average length of the leaf rachis and those predicted by the model were strongly related (Figure 3). The statistical evaluation of the model expressing the relationship among the data sets indicated, according to the hypotheses (Equation 4), the equivalence between the predicted and observed values ($P < 0.05$).

The total leaf area was estimated by using both equations (5) and (6). Using independent data, the statistical evaluation of the relationship (Figure 4) indicated similarity for predicted and observed values, based on the hypothesis specified in (4). As stated by Robbins & Pharr (1987), the model adjusted has a balance between predictive qualities and the economy of including the least number of variables necessary to predict the total leaf area.

In general, the obtained model was satisfactory for estimating total leaf area of the green dwarf coconut tree. It was possible, from Equation 7, to set up the set of response lines shown in Figure 5. This abacus allowed estimated values of the total leaf area of one tree to be easily determined from the length average of the last three leaf rachis and the leaf numbers in the crop canopy.

$$TLA = 0.8282\ \{ -0.3125 + 1.3207\ [LR3] - 0.2078\ [LR3]^2 + 0.05407\ [NL]\}^{1.5662} \quad (7)$$

While the model does not include any variable that characterizes it for the specific conditions found in the northern region of Rio de Janeiro state, its accuracy should be evaluated before application in other regions.

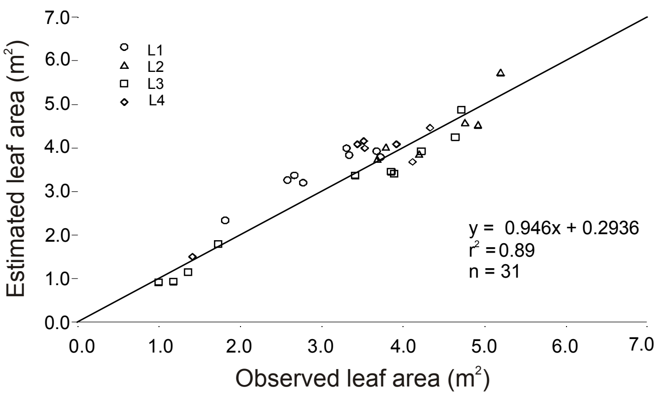

Figure 2 - Relationship between the observed individual leaf areas and the estimated ones of the dwarf coconut tree at four differents areas.

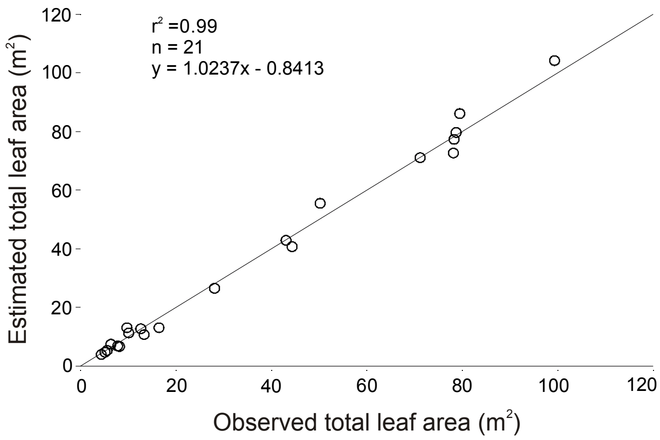

Figure 4 - Correspondence between the observed and estimated values of the total leaf areas in the green dwarf coconut tree's canopy.

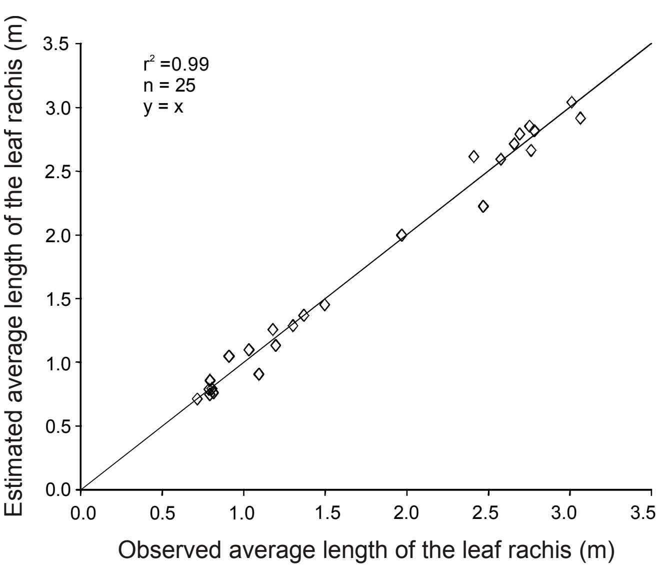

Figure 3 - Correspondence between the observed and estimated values (from Equation 6, see text) of the average length of the leaf rachis in the green dwarf coconut tree's canopy.

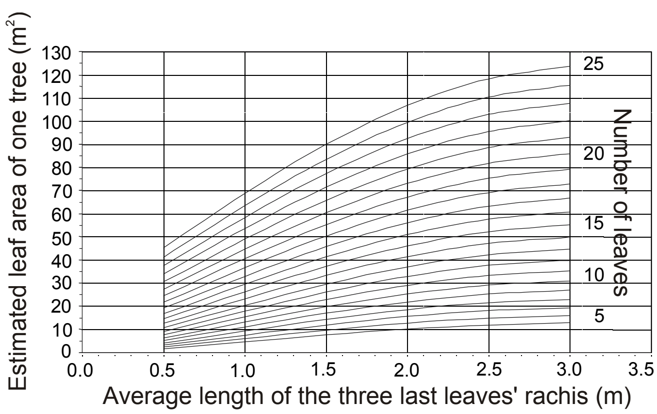

Figure 5 - Prediction lines for estimating the leaf area a tree of green dwarf coconut from the average length of the last three leaves' rachis and the number of leaves in the canopy.

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REFERENCES

CAMPOSTRINI, E.; YAMANISHI, O.K. Estimation of papaya leaf area using the central vein length. **Scientia Agricola**, v.58, p.39-42, 2001.

GAMIELY, S.; RANDEL, W.M.; MILLS, H.A.; SMITTLE, D.A. A rapid and nondestructive method for estimating leaf area of onions. **HortScience**, v.26, p.206, 1991.

GONÇALVES, C.A.A.; CHALFIN, N.N.J.; REGINA, M.A.; ALVARENGA, A.A.; SOUZA, M.T.; ABRAÃO, E. Estimativa da área foliar da videira (*vitis labrusca* L. cv. Folha de Figo) sobre diferentes porta-enxertos. **Ciência e Agrotecnologia**, v.26, p.500-504, 2002.

NESMITH, D.S. Nondestructive leaf area estimation of Rabbiteye Blueberries. **HortScience**, v.26, p.1332, 1991.

NOBEL, P.S. **Physicochemical and environmental plant physiology**. San Diego: Academic Press, 1991. 635p.

NORMAN, J.M.; CAMPBELL, G.S. Crop structure. In: PEARCY, R.W.; EHLERINGER, J.R.; MOONEY, H.A.; RUNDEL, P.W. **Plant physiological ecology**: Field methods and instrumentation. New York: Chapman and Hall, 1989. p.457.

PANTA, G.R.; NESMITH, D.S. A model for estimating area of Muskmelon leaves. **HortScience**, v.30, p.624-625, 1995.

PEREIRA, A.R.; VILLA NOVA, N.A.; SEDIYAMA, G.C. **Evapo(trans)piração**. Piracicaba: FEALQ, 1997. 183p.

PEREIRA, J.F.; SPLITTSTOESSER, W.E. A rapid method to estimate leaf area of cassava plants. **HortScience**, v.21, p.1218-1219, 1986.

RAO, G.S.P.; KHAN, B.H.; CHADHA, K.L. Comparison of methods of estimating leaf-surface area through leaf characteristics in some cultivars of *Mangifera indica*. **Scientia Horticulturae**, v.8, p.341-348, 1978.

ROBBINS, N.S.; PHARR, D.M. Leaf area prediction models for cucumber from linear measurements. **HortScience**, v.22, p.1264-1266, 1987.

TAIZ, L.; ZEIGER, E. **Plant physiology**. Redwood City: The Benjamin/ Cummings Publishing Company, 1991. 559p.

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