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Estimating the Leaf Area of *Irvingia Gabonensis* (Aubry-Lecomte Ex O' Rorke) Baill from Linear Measurement

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Abstract

Leaf area measurements are of great value in physiological and agronomic studies. Leaf area is important for plant light interception, growth analysis, photosynthesis, leaf area index estimation among others. This study focused on estimating the leaf of *Irvingia gabonensis* using a linear (non-destructive) measurement. A total of 90 leaves were selected randomly from nursery and field which represented different leaf sizes ranging from small (3 cm width), medium (5 cm width) and large (7 cm width). The lamina length (L) and lamina width (W) were measured with a ruler, while the leaf area (LA) were measured using a software model WinRHizo PRO2005, installed on computer system with an attached scanning machine. The best fit model was selected based on F test and coefficient of determination R^2. Correlation of all parameters is significant at 1% level. Product of square length and width $[(LW)^2]$ correlated best with leaf area having a correlation coefficient (r) of 0.99. Quadratic and linear regression of the data produced thirteen leaf area models. The best five models were derived from single dimensional measurement product and sum of length and width of either lamina length or width. The five top models were recommended for leaf area estimation of *Irvingia gabonensis* but for ease of application, model 13 (Y = 0.2309x2- 2.5694x + 67.268: R^2 = 99%) was preferred for its simplicity. The models developed and recommended in this study can be adopted for rapid and accurate estimation of adaxial leaf area of *I. gabonensis* under field conditions.

Keywords: determination coefficient, leaf area, linear measurement, non-destructive, *Irvingia gabonensis*

1. Introduction

Leaf area is an important variable for most ecophysiological studies in terrestrial ecosystems concerning light interception, evapotranspiration, photosynthetic efficiency, fertilizers, and irrigation response and plant growth (Blanco & Folegatti, 2005). Plant physiologists require leaf area measurements for studying primary production in plants (Bleasdale, 1984). Ecologists use leaf area relations for elucidating competition among different plant species (Harper, 1977). Leaf area estimate is valuable in studies of plant nutrition, plant competition, plant-soil-water relations, plant protection measures, respiration, light reflectance, and heat transfer in plants, and thus it is an important parameter in understanding photosynthesis, light interception, water and nutrient use, and crop growth and yield potential (Smart 1974; Williams, 1987). Leaf area is important for crop light interception and therefore has a large influence on growth (Boote, Jones, & Hoogenboom, 1998), transpiration (Enoch & Hurd, 1979) and growth rate (Leith, Reynolds, & Rogers, 1986). Leaf area production is essential for energy transference and dry matter accumulation processes in crop canopies. It is also useful in the analysis of canopy architecture as it allows for the determination of leaf area index, which is important for light interception, radiation use efficiency, plant growth among others.

Leaf area measuring instruments are very expensive and often not available in developing countries and remote research stations. When available, these instruments are prone to large errors as a result of incorrect use that may lead to inconclusive results (de Jesus, Dovale, Coelho, & Costa, 2001). These problems have been recognized by many researchers, who have developed less expensive and/or alternative, indirect methods (Ma, Gardner, & Selamat, 1992). Indirect methods are based on the assumption that mass and size dimensions of different plant parts are allometric (Gardner, Pearce, & Mitchell, 1985). These indirect methods may increase precision of leaf area determination where sample or leaf size are difficult to handle (Ma et al., 1992) and can reduce the overall sampling effort necessary to estimate leaf area (Lieth et al., 1986). Indirect methods of measuring leaf area can be classified as non-destructive and destructive methods. In non-destructive methods, leaf area is usually estimated by measuring the number, width or length of plant parts or whole plant. These measurements can be undertaken without cutting the plants. Non-destructive methods have been successfully applied for various crops such as cotton and castor (Wendt, 1967), sorghum (Shih, Gascho, & Rahi, 1981), soybean (Lieth et al., 1986), pearl millet (Payne, Wendt, Hossner, & Gates, 1991), maize (Stewart & Dwyer, 1999) and sunflower (Bange, Hammer, Milroy, & Rickert, 2000). Non-destructive estimation of leaf areas offers researchers reliable and inexpensive alternatives in plant research studies. Non-destructive leaf-area or plant growth measurements are often desirable because continued use of the same plant over time can reduce variability in experiment when compared with destructive sampling (Nesmith, 1991). The determination of leaf area using this method involves measuring lengths, widths and areas of leaf samples and calculating the several possible regression coefficients or leaf factors to estimate areas of subsequent samples (Silva, Ferreira, Fontes, & Cardoso, 1998; Gutienez & Larvin, 2000; Astegiano, Favaro, & Bouzo, 2001; Guo & Sun, 2001; Jayeoba, Oluwasemire, Abiola, Uzokwe, & Ogunbajo, 2006).

Irvingia gabonensis is a member of the family *Irvingiaceae* and locally known as "Ogbono" in Southwestern Nigeria. It is naturally distributed in several West African countries such as Ghana, Togo, Cameroon, Senegal, Benin, and Nigeria among many others. Its bark is an excellent medicinal product (Van Dijk, 1999), the mesocarp of its fruit is consumed fresh and the kernels extracted from the fruit are used as basic soup ingredients. A type of oil is extracted from the hot almond paste and can be used as a cosmetic product, as food or in pharmacopoeia (Awono, Djouguep, Zapfack, & Ndoye, 2009). Its seed (kernel) serves as soup thickener which provides carbohydrate, oil and protein so enhancing health and nutrition. There has been a massive depletion of its stocks in African forests, while natural regeneration of the species has also been constrained by wild animals. Consequently due to a combination of these constraints, the available stocks in the nursery are usually guided jealously. Therefore all physiological and agronomic study of this plant had to be conservative in design. This justified the need for the development of leaf factors for non-destructive leaf area measurement of the plant.

2. Materials and Methods

2.1 Plant Material

Leaf samples from selected seedlings of *Irvingia gabonensis* in the tree crop nursery of Forestry Research Institute of Nigeria (FRIN), Jericho, Ibadan were used for the study. Various leaf sizes (30 each of small-sized, medium-sized and large-sized) were selected from the nursery stock and matured stands of *I. gabonensis* over a period of three months. The study was carried out at the nursery of the Forestry Research Institute of Nigeria (FRIN), Ibadan, Nigeria (7° 26'N; 3° $26^{'}$E).

2.2 Methodology

The leaf area (LA) of the leaves was measured using a software model WinRH120 PRO 2005, installed on computer system with an attached scanning machine. The lamina length (L) and lamina width (W) were measured from the lamina tip to the point of petiole intersection along the lamina midrib and edge to edge at the widest part of the lamina respectively with the aid of a well graduated meter rule. The data generated were filled to linear and quadratic regressions of L and W. Actual leaf area was taken as the dependent variable (Y) and the combinations of L and W as the independent variable (X), correlation analysis of the leaf area (LA) and of the independent variables L, W, L^2, W^2, L+W, and LW were calculated. Statistical criteria for model selection were based on correlation coefficient (r) and coefficient of determination (R^2).

3. Results

3.1 Correlation Analysis

The results showed that there is a strong significant relationship between leaf area and all the parameters studied at 1% level (Table 1).

Table 1. Correlation matrix of leaf area and linear leaf measurement of *Irvingia gabonensis*

	L (cm)	W (cm)	L (cm)	LW (cm²)	L+W (cm)	L^2 (cm²)	W^2 (cm²)	L+L (cm)	W+W (cm)	$(LW)^2$ (cm²)	$(L+L)^2$ (cm²)	$(W+W)^2$ (cm²)	LA (cm²)
L (cm)	1												
W (cm)	0.942482	1											
L (cm)	0.799451	0.750913	1										
LW (cm²)	0.980061	0.979554	0.795894	1									
L+W (cm)	0.994193	0.972979	0.793986	0.992355	1								
L^2 (cm²)	0.994132	0.937165	0.806261	0.985285	0.988428	1							
W^2 (cm²)	0.935244	0.993391	0.759617	0.983905	0.965852	0.939303	1						
L+L (cm)	1	0.942482	0.799451	0.980061	0.994193	0.994132	0.935244	1					
W+W (cm)	0.942482	1	0.750913	0.979554	0.972979	0.937165	0.993391	0.942482	1				
$(LW)^2$ (cm²)	0.944283	0.942572	0.791352	0.98248	0.955734	0.967692	0.966338	0.944283	0.942572	1			
$(L+L)^2$ (cm²)	0.994132	0.937165	0.806261	0.985285	0.988428	1	0.939303	0.994132	0.937165	0.967692	1		
$(W+W)^2$ (cm²)	0.935244	0.993391	0.759617	0.983905	0.965852	0.939303	1	0.935244	0.993391	0.966338	0.939303	1	
LA (cm²)	0.976497	0.960744	0.808377	0.988254	0.983837	0.980599	0.963114	0.976497	0.960744	0.970455	0.980599	0.963114	1

Table 1 shows the correlation analysis of the parameters studied against Leaf Area (LA).

Key: L = Length; W = Width (breadth); LA = Leaf area.

3.2 Generation and Testing of Models

Table 2 shows all the possible equations generated for the estimation of leaf area in *I. gabonensis*, all of which are significant at 1%. The graphical representations of the linear models tested were shown in Figures 1-9. The relationship between LA and LW was observed to be linear and significant at 1% with the correlation coefficient (r) of 0.93 (Figure 1). Similar trends of linear and significant relationship were observed in the relationship between LA and L+W with the correlation coefficient (r) of 0.96 (Figure 2), between LA and L^2 with the correlation coefficient (r) of 0.92 (Figure 3); and between LA and (L+L) with the correlation coefficient (r) of 0.96 (Figure 4), between LA and W with the correlation coefficient (r) of 0.99 (Figure 5), between LA and (W+W) with the correlation coefficient (r) of 0.93 (Figure 6), between LA and L with the correlation coefficient (r) of 0.97 (Figure 7), between LA and W^2 with the correlation coefficient (r) of 0.93 (Figure 8) and between LA and $(LW)^2$ with the correlation coefficient (r) of 0.99 (Figure 9).

However, it should be noted that model 13 for the relationship between L and [$(LW)^2$] gave the best fit at R^2 = 99.4% (Figure 2), while models developed for the relationships between LA and L+W, LA and W, LA and LW as well as LA and L with the corresponding R^2 values of 97.9%, 97.8%, 97.7% and 97.2% respectively were also tested to be good and can also be applied as well (Table 2).

Table 2. Equations for possible estimation of *Irvingia gabonensis* leaf area

Parameters	Equations/Model	R^2 Value
LW	$Y= 6E\text{-}06x^2 + 0.4672x - 0.0231$	0.977
L+W	$Y=0.0002x^2+0.1215x + 4.8975$	0.979
L^2	$Y=0.0003x^2 + 1.0902x - 0.4566$	0.962
L+L	$Y=0.0003x^2 + 0.1682x + 6.855$	0.965
W	$Y= -5E\text{-}05x^2+0.0353x + 1.491$	0.978
W+W	$Y=4.1021Ln(x)-9.625$	0.959
L	$Y=0.0535x + 4.5815$	0.964
L	$Y=4.3573Ln(x)-9.6335$	0.965
L	$Y=0.0002x^2 + 0.0826x + 3.4765$	0.972
W^2	$Y=0.2108x-0.1909$	0.928
$(LW)^2$	$Y=42.113x-1625.4$	0.952
$(LW)^2$	$Y=149.85e^{0.0241x}$	0.954
$(LW)^2$	$Y=0.2309x^2-2.5694x + 67.268$	0.994

The equations/models generated for the estimation of the leaf area of *Irvingia gabonensis.*

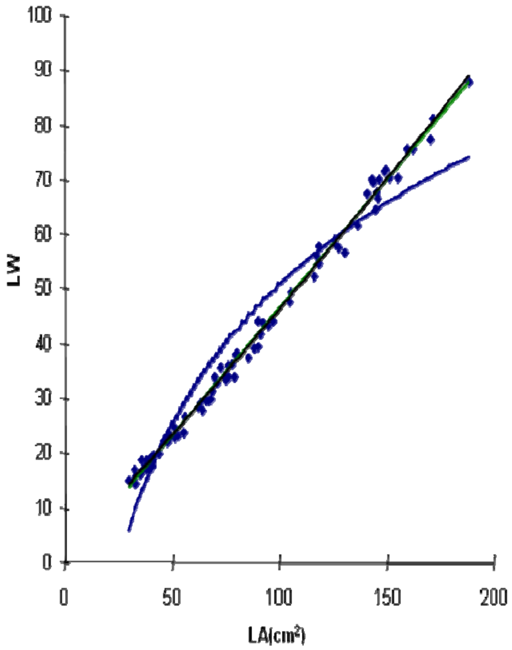

Figure 1. Relationship between leaf area (LA) and the product of Lamina leaf length and width (LW) of *Irvingia gabonensis*

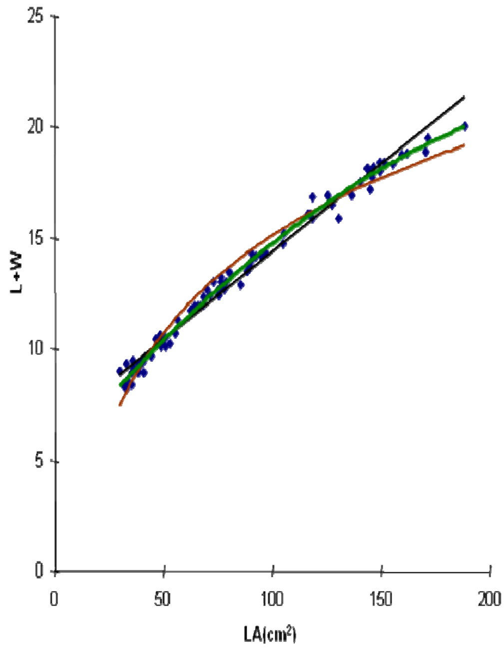

Figure 2. Relationship between leaf area (LA) and summation of lamina leaf length and width (L+W) of Irvingia gabonensis

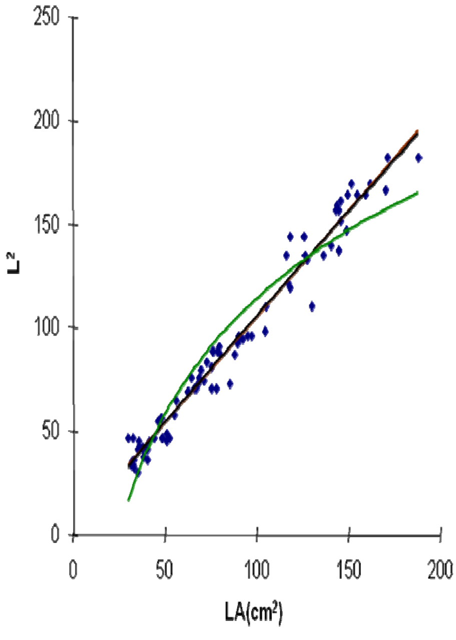

Figure 3. Relationship between leaf area (LA) of leaf and square lamina leaf length (L2) of Irvingia gabonensis

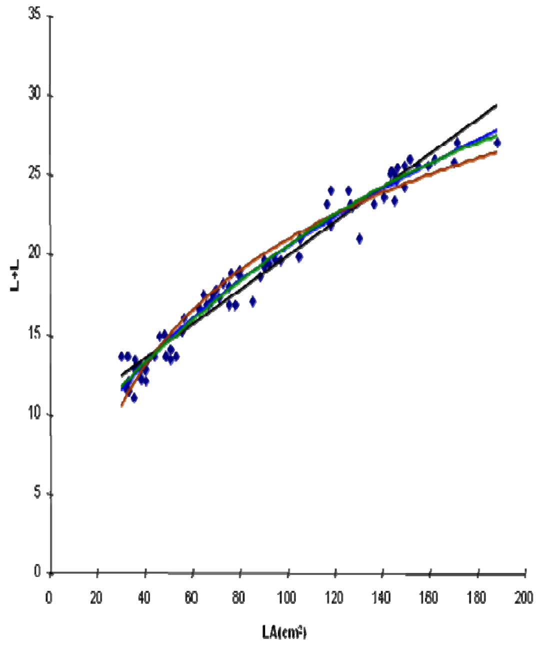

Figure 4. Relationship between leaf area (LA) and summation of lamina leaf length and length (L+L) of Irvingia gabonensis

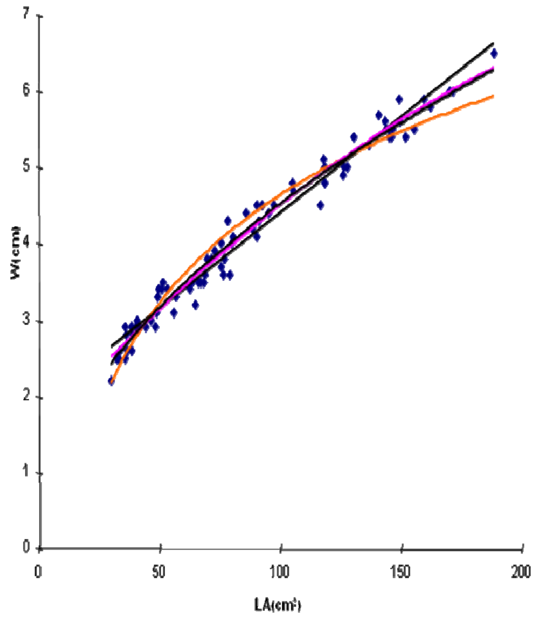

Figure 5. Relationship between leaf area (LA) and lamina width (W) of *Irvingia gabonensis*

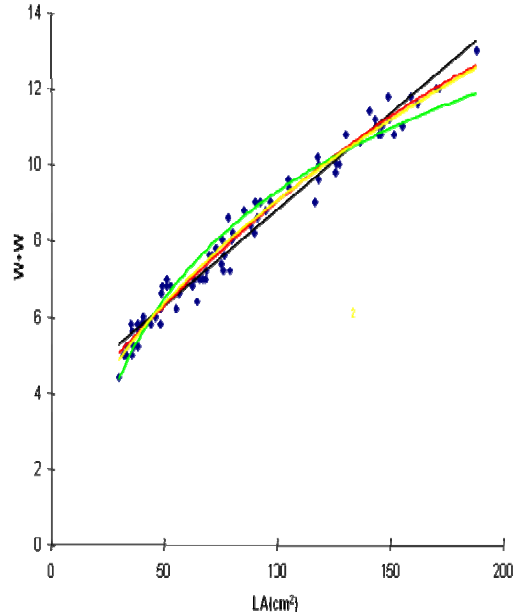

Figure 6. Relationship between leaf area (LA) and summation of lamina width and width (W+W) of *Irvingia gabonensis*

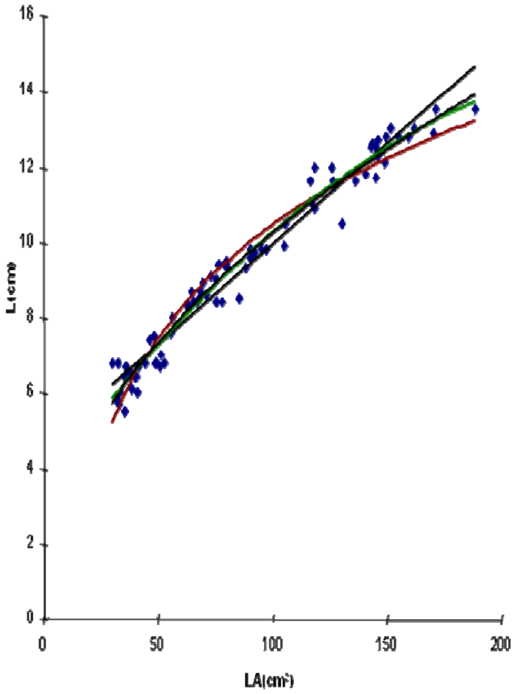

Figure 7. Relationship between leaf area (LA) and lamina leaf length (L) of *Irvingia gabonensis*

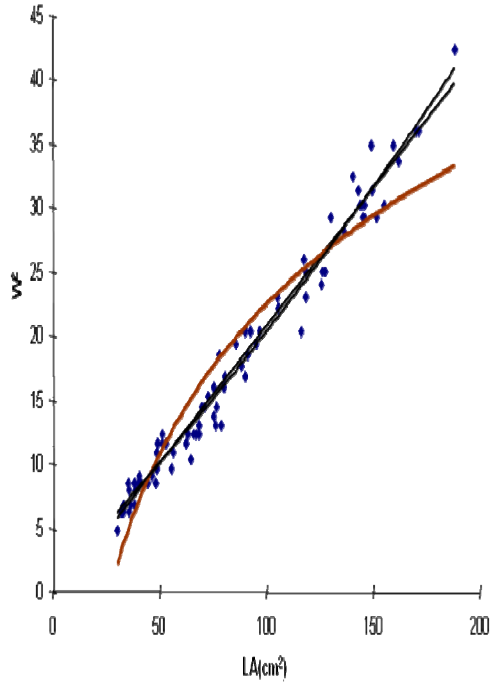

Figure 8. Relationship between leaf area (LA) and square lamina leaf Width (W2) of *Irvingia gabonensis*

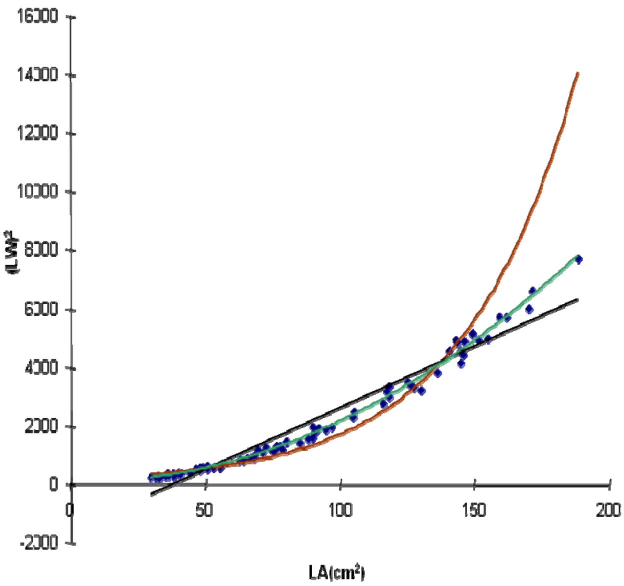

Figure 9. Relationship between leaf area (LA) and the product of square lamina leaf length and width [(LW)2] of *Irvingia gabonensis*

4. Discussions and Conclusion

The models developed from this study will enable crop scientists including tree breeders, agronomists and horticulturist that may be interested in the study of growth and development of *Irvingia garbonensis* either in the field or at the nursery stage without destroying the leaves thereby compromising on precision and accuracy. The linear relationship between the LA and [$(LW)^2$] gave the best bit and the model, $Y = 0.2309x^2 – 2.5694x + 67.268$: $R^2 = 99\%$ is recommended for predicting leaf area. Furthermore, models developed for the relationships between LA and L+W, LA and W, LA and LW, LA and L were also good. The models developed and recommended in this study can be adopted for rapid and accurate estimation of adaxial leaf area of *I. gabonensis* leaves under field conditions. Furthermore, non-destructive determination of leaf area by the model assures repeated measurement of leaves in growth monitoring experiments, while the model serves as a good substitute where leaf area meter or sophisticated expertise is not available.

Similar results were obtained between LA and W, LA and W^2, and LA and LW in cabbage (Olfati, Peyvast, Shabani, & Nosratie-Rad, 2010) and shea butter (Ugese, Baiyeri, & Mbah, 2008). Pandey and Singh (2011) reported that the non-destructive estimates of leaf area by graphical method are as good as those obtained destructively by leaf area meter method.

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