# Predicting Single-Sided Leaf Area in a Broadleaf Forest Given Leaf Weight

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## Abstract

Four proportionality models for predicting single-sided leaf area in a broadleaf forest given leaf weight are proposed. The leaf area calculated by each proposed model is compared to the leaf area calculated by the other models, and to the leaf area as determined by litter trap data and an image processing program. The best of the four models is chosen to serve as part of larger study into the evapotranspiration rates of broadleaf forest across the southeast United States.

## I. Introduction

Leaf area index (LAI) is an important parameter when performing forest studies. McIntyre (1990) developed a model, based on the Beer-Lambert law, for calculating LAI to further study atmospheric deposition to a forest. McIntyre's model used litter trap data as the standard against which it was compared. Breda (2003) notes that LAI is one of the most difficult parameters in ecophysiology to quantify, a point with which this author agrees.

Leaf area index, and leaf area by extension, is an important parameter needed as part of a larger ongoing study into the effects of climate on evapotranspiration rates of broadleaf forests across the southeast United States. This paper formulates and discusses a model for predicting single-sided leaf area given leaf weight.

## II. Methodology

Five sets of leaves were gathered for this study, with data given in Table 1. The leaves were dried before the weight and one-sided area were determined. Weight, in grams and including the stem, was measured per set on a scale. One-sided area was determined by a two step process. First, each leaf was scanned on a flatbed scanner at 100 dots per inch. Next, the area of each leaf, in pixels and not including the stem, was determined by running the scanned leaf images through an image processing program (IPP). The area was converted from pixels to inch$^2$ by the following formula: $Area_{inch^2} = \frac{Area_{pixels}}{10000_{dots\ per\ inch^2}}$. (Eq. 1)

| **Leaf_collection** | **Number** | **Weight(gram)** | **Area(inch$^2$)** |
|---|---|---|---|
| Set 1 | 100 | 40 | 759.6 |
| Set 2 | 77 | 40 | 741.6 |
| Set 3 | 30 | 13 | 231.8 |
| Set 4 | 20 | 7 | 121.8 |
| Set 5 | 34 | 9 | 137.7 |

**Table 1 - Leaf Collection Data**

## III. Data and Analysis

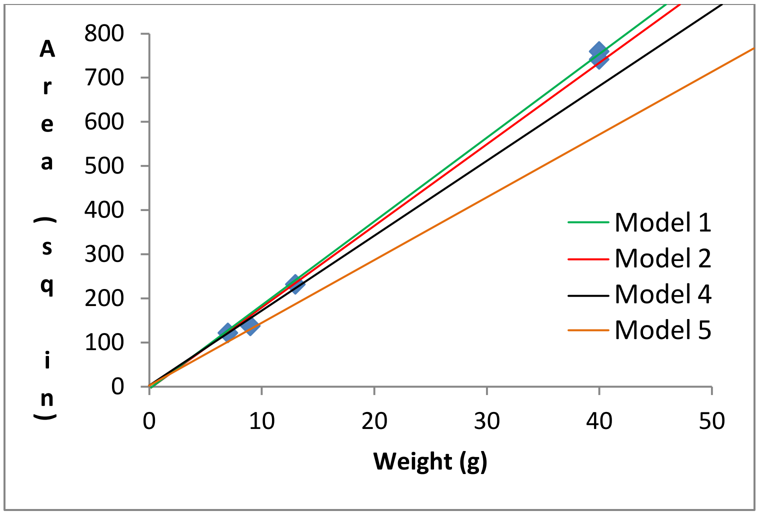
Four models were developed from the data to study leaf area in relation to leaf weight. Model 1 was developed from Set 1, Model 2 was developed from Set 2, Model 4 was developed from Set 4, and Model 5 was developed from Set 5. No model was developed for Set 3, as it will be used for validation. Each model is a proportionality model of the form: $Area_{inch^2} = k_{Model\ i} * Weight_{grams}$(Eq. 2), where proportionality constant $k_{Model\ i}$ is the slope between the point $(Weight_{Set\ i}\ ,\ Area_{Set\ i})$ and the origin. Formally stated: $k_{Model\ i} = \frac{Area_{Set\ i} - 0}{Weight_{Set\ i} - 0}$ (Eq. 3). In each equation, $i$ is an element of {1,2,4,5}. Table 2 illustrates the area for each Set as predicted by each Model. A fifth row, with the areas as determined by the IPP, is provided for comparison.

| **Model** | **Set 1 Area** Weight = 40g | **Set 2 Area** Weight = 40g | **Set 3 Area** Weight = 13g | **Set 4 Area** Weight = 7g | **Set 5 Area** Weight = 9g |
|---|---|---|---|---|---|
| IPP | 759.6 | 741.6 | 231.8 | 121.8 | 137.7 |
| 1, $k_1$ = 18.99 | 759.6 | 759.6 | 246.87 | 132.93 | 170.91 |
| 2, $k_2$ = 18.54 | 741.6 | 741.6 | 241.02 | 129.78 | 166.86 |
| 4, $k_4$ = 17.4 | 696 | 696 | 226.2 | 121.8 | 156.6 |
| 5, $k_5$ = 15.3 | 612 | 612 | 198.9 | 107.1 | 137.7 |

**Table 2 - Area ($inch^2$) Determined From Models 1, 2, 3 and 4**

## IV. Results

The following discussion compares area predicted by each model with the area calculated by the IPP. The $k$ values determined for Models 1 and 2 were, as expected, very similar due to the equal weight and near equal area used in their calculations. These two models both over predicted the area for Sets 3, 4 and 5 but were reasonably accurate for Sets 3 and 4. Model 4 under predicted the area for Sets 1 and 2, but over predicted the area for Set 5. It was very accurate for Set 3. Model 5 was the least accurate of the four models. It consistently under predicted the area for Sets 1, 2, 3 and 4, and its prediction became less and less accurate as the weight increased. Plot 1 visually presents the four models, and reinforces the results.




**Plot 1 - Plot of Table 1 Weight vs. Area With Model Lines Overlaid**

## V. Conclusions

Overall, considering the given data, Model 1 is the best model to calculate single-sided leaf area given leaf weight. This model very accurately predicts the area for Sets 1 and 2 and is reasonably accurate for Sets 3 and 4. While it does heavily over predict the area of Set 5, it is the most suitable of the four models for extrapolating the area for weights beyond 40 grams. This study employs linear models, and common sense suggests a linear model is the best choice for the study. However, since the data visually suggest a slight curve, perhaps a non-linear model, maybe quadratic, would better serve as a model for the study.

Using a different class of model may not yield more accurate results, but there are several methodological refinements that would most certainly yield more accurate results. Leaf stems add an assumed non-negligible, but still small, amount of weight to the overall leaf weight, but were not included in the leaf area calculation by the IPP. This discrepancy, which likely contributes to the slight curve in the data mentioned previously, should be less pronounced as overall leaf weight increases. Removal of the stems before weighing would likely lead to development of a more accurate model. Also, other properties of the collected leaves should be kept as uniform as possible. These include: using leaves from the same or acceptably related species of tree, and ensuring that each leaf holds as uniform an amount of moisture as possible. Additionally, consider discarding leaves whose full shape is intact, but who are missing some portion of inner leaf material. Such leaves will have a lower weight, but identical area by the IPP calculation, as compared to a fully intact leaf.

Four more refinements are worthy of consideration. In Eq. 1, notice that the numerator has unit of pixels, whereas the denominator has unit of dots per inch$^2$. It is necessary to ensure that one dot in fact equals one pixel. In addition, consider that a higher resolution will likely produce a more accurate area calculation through the IPP, and a more accurate weighing process and device will produce a more accurate weight. Finally, use of heavier sets of leaves for model development and validation will provide a more accurate representation of leaf area in a forest, considering the large number of leaves found in a forest.

## References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Breda, N.J.J., 2003, Ground-based measurements of leaf area index: a review of methods, instruments and current controversies. Journal of Experimental Botany, Volume 54, Issue 392, Pp. 2403-2417. http://jxb.oxfordjournals.org/content/54/392/2403.full