



A quick and simple method for estimating leaf area by leaf weight

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Abstract

Leaf area is an important plant functional trait in understanding eco-physiological processes in terrestrial ecosystems. Estimating leaf area from equations utilising leaf dimensions is a cost-effective, time-saving and non-destructive method of determining leaf area. Present paper deals with a new, inexpensive and quick method (leaf weight method) based on leaf weight and weight of its segment. Investigations were carried out on 20 species consisting of different life forms, procured from Botanical Garden, Dr. H.S. Gour University, Sagar, India. Estimates of leaf area were calculated by the equation devised, $\text{leaf area (cm}^2\text{)} = \frac{x}{y} \times m$. Where x and y represent an area of a known leaf segment and weight (g) of the same segment respectively and m is the weight of the whole leaf/leaflet. These estimates were compared with the leaf area determined by the leaf area meter. The two estimates were found significantly and linearly related. Hence, the leaf weight method can be used for leaf area measurement for any leaf/leaflets irrespective of their size and shape and thickness.

Keywords: leaf trait, leaf area, leaf weight, leaf segment weight

Introduction

Leaf area is an important plant functional trait in understanding eco-physiological processes in terrestrial ecosystems. It is strongly associated with a light interception, photosynthetic efficiency, evapotranspiration and plant growth (Blanco and Folegatti 2005)^[3]. It is related to primary production (Sestak et al. 1971; Tieszen 1982; Bleasdale 1984)^[29, 33, 4], inter and intraspecific competition (Harper 1977)^[11], plant-soil-water relations, heat transfer in plants (Mohsenin 1986; Sestak et al 1971)^[19, 29]. It is valuable in studies of plant nutrition, plant protection and light reflectance. For a long time, plant scientists have been concerned about estimating leaf surface area in a simple, cost-effective, and precise manner. Direct and indirect approaches can be used to determine the leaf area. Leaves are plucked from the plant and measurements are taken using expensive tools such as a digital leaf area metre in the direct methods (destructive methods). Non-destructive methods (regression techniques) based on linear measurements of plant leaves, rather, are generally precise, faster, and easier to adopt in a variety of crops (Strik and Proctor 1985; Norman and Campbell 1989, Guo and Sun 2001)^[33, 22, 15]. Some researchers have used image processing techniques for fast and accurate measurement of leaf area (Chaohui et al 2010, Tan and wang 2010, Chaudhari et al 2012)^[6, 34, 7]. Electronic metres can only be utilised if the plants have sparse and nonfragile leaves (Tieszen 1982, Bleadsdale 1984)^[35, 4]. Brodny et al (1986)^[5] describe a variety of computerized image analysis equipment and software. They use a portable scanning planimeter to measure rapidly, accurately, and non-

destructively (Daughtry 1990)^[10], however, the technology is only suited for small plants with few leaves (Nyakwende et al 1997)^[23] and is cost-intensive (Bignami and Rossini 1996)^[2]. Digital leaf area meter instrument can only be used in a suitable environment during laboratory applications and cannot be used during field experiments. Various combinations of measures and models concerning the length and width of the area have been developed for several fruit trees such as grape (Montero et al 2000; Williams and Martinson 2003)^[21, 39], avocado (Uzun and Celik 1999)^[38], pistachio (Ranjbar and Damme 1999)^[25], cherry (Demirsoy and Demirsoy 2003)^[12], peach (Demirsoy et al 2004)^[13], and chestnut (Serdar and Demirsoy 2006)^[30]. Few types of research also focussed on petiole length (Manivel and Weaver 1974)^[18] and leaf weight (Sepulveda and Kliever 1983, Montero et al 2000)^[29, 21]. The most notable trend involves developing ratios and regression estimators using easily measured foliar parameters like length and width. The simple and linear connections between leaf area and leaf dimensions (length, breadth) could be effective for the non-destructive assessment of leaf area (Lu et al 2004)^[17]. Estimating leaf area from equations utilising leaf dimensions is a cost-effective, time-saving, and non-destructive method of determining leaf area. Non-destructive models for determining leaf area have been developed for many species such as maize (Stewart and Dwyer 1999)^[32], bean (Bhatt and Chanda 2003)^[11], taro (Lu et al 2004)^[17], white clover (Gamper 2005)^[14], sugar beet (Tsialtas and Maslaris 2005, 2008)^[36, 37], sunflower (Kvet and Marshall 1971; Rouphael et al 2007)^[16, 27], zucchini (Rouphael et al 2006)^[26], radish (Salerno et al 2005)^[28],

grapevine (Manivel and Weaver 1974; Montero et al 2000, Williams and Martinson 2003) [18, 21, 39], kiwi (Mendoza-de Gyves et al 2007) [19] and chestnut (Serdar and Demirsoy 2006) [30]. However, leaves can have complicated geometries, calculating leaf area using ratios of leaf characteristics can be difficult, time-consuming, require instrumentation and error-prone.

Therefore, the study aims to develop a simple, cost-effective, leaf shape and size-independent method for leaf area estimation based on the weight of the leaf and its segment of definite size.

Material and Methods

Leaves of 20 plant species including herb, shrub, tree and climber were collected from the Botanical Garden (N23°49'48.18", E078°46'36.28) of the Department of Botany, Dr Harisingh Gour University, Sagar, Madhya Pradesh, India, during the rainy season from the month of August-September, 2019. Ten leaves from the upper, middle and lower parts of each species were taken. The leaves we collected were evenly distributed in thickness due to which we have not focussed on thickness in our measurement criteria. Leaf segments of known size and shape (square in the present study) were cut from each leaf/leaflet. The whole leaf and its section area were weighed using an electronic weighing machine. Simultaneously, the leaf area of the entire leaf/leaflet was measured using SYSTRONICS Leaf Area Meter 211. The following equation was developed to measure the leaf area:

$$\text{Leaf Area (LA)} = \frac{x}{y} \times m$$

Where x and y represent the leaf segment area (cm²) and its weight (g) respectively, while m represents the weight (g) of the entire leaf.

The two sets of estimates of leaf area (Leaf area meter and leaf weight method) were related according to equation Y = a + bx, where Y is the leaf area estimated by leaf area meter and x is the leaf area estimated by equation developed using

leaf segment weight and weight of entire leaf. The independent variable here was the leaf area estimated by millimetre graph paper, and the dependent variable was leaf area estimated by leaf area meter (SYSTRONICS, Leaf Area Meter-211). The regression equations were calculated following the standard statistical method.

Results and Discussion

Leaf area as estimated by leaf area meter (dependent variable) and that estimated by the equation developed on a weight basis (independent variable) for 20 plant species are given in Table 1. The coefficient of determination between two sets of estimates for species under consideration varied from 0.789 to 0.999 and collectively the R² was 0.996 (Fig. 1). Chi-square test (χ^2) for dependent and independent variables showed no significant differences in estimates.

Earlier methods based on easily measured leaf parameters are usually dependent on the variation of leaf shape (Cristofori et al 2007, 2008; Zang and Liu 2010) [9, 8, 40]. The shortcomings of the millimetre graph paper method usually lack proper spread of paper, accurate drawing of leaf margins and lack of even cutting of the drawn outline (Pandey and Singh 2011) [24]. The present method is independent of leaf size, shape, thickness and moisture. However, the method is most suitable for leaves with even thickness in comparison to those where the biomass is not uniformly distributed in leaves. It provides more suitable results in herb and climber while in trees result deviated with mass distribution and not utilized in very small size leaf or fleshy leaf. This method can be utilized to estimate a large amount of leaf and leaf litter where accuracy is less important.

The method developed in the present experiment needs only a weighing machine and a cutting borer with sharp edges. The accuracy of leaf area estimation in the present method is reasonably good.

Therefore, this quick, less expensive and simple method can be used for estimation of leaf area of plants irrespective of shape, thickness and size of leaves.

Table 1: Regression equations and coefficient of determination (R²) between leaf area measured by leaf area meter (LAM) and leaf weight method (WM) for two plant species (χ^2 p < 0.05 at 9 df).

Sr. No.	Name of species	Growth Form	Leaf Area (cm ²) (LAM) mean ± SE	Leaf Area (cm ²) (WM) mean ± SE	Regression equation	R ²	χ^2
1	<i>Euphorbia geniculata</i> Ort.	Herb	29.2±1.74	28.8±1.52	Y=0.846x-4.060	0.956	0.071
2	<i>Nyctanthus arbor-tristis</i> L.	Shrub	22.8±1.17	23.4±0.96	Y=0.807x+4.987	0.948	0.078
3	<i>Cassia uniflora</i> Mill.	Herb	7.7±0.78	7.6±0.76	Y=0.946x+0.310	0.963	0.012
4	<i>Solanum nigrum</i> L.	Herb	32.2±0.55	31.3±0.60	Y=1.038x-2.151	0.944	0.125
5	<i>Catharanthus roseus</i> (L.) G.Don	Herb	12.9±0.92	12.8±1.00	Y=1.067x-2.317	0.963	0.006
6	<i>Cinnamomum tamala</i> T.Nees	Tree	31.5±1.55	32.1±1.45	Y=0.930x+2.830	0.961	0.134
7	<i>Antigonon leptopus</i> Hook. & Arn	Climber	34.9±1.31	34.6±1.13	Y=0.840x-5.268	0.954	0.025
8	<i>Hibiscus rosa-sinensis</i> L.	Shrub	48.4±1.57	47.1±1.61	Y=1.011x-1.842	0.999	0.209
9	<i>Diplocyclos palmatus</i> (L.) C. Jeffrey	Climber	70.3±3.06	71.7±2.57	Y=0.843x+12.12	0.990	0.089
10	<i>Saraca asoca</i> (Roxb.) Willd.	Tree	32.4±1.60	33.4±1.46	Y=0.922x+3.511	0.988	0.308
11	<i>Grewia asiatica</i> L.	Tree	48.2±1.37	48.8±1.34	Y=0.964x-2.317	0.960	0.074
12	<i>Euphorbia pulcherrima</i> Willd. ex. Klotzsch	Shrub	33.5±1.67	33.2±1.57	Y=0.914x+2.562	0.962	0.012
13	<i>Alstonia scholaris</i> (L.) R.Br.	Tree	53.0±2.14	53.0±1.93	Y=0.904x+6.044	0.989	0.233
14	<i>Ageratum conyzoides</i> L.	Herb	27.0±0.69	28.7±0.73	Y=0.879x+1.783	0.932	0.988
15	<i>Lantana camara</i> L.	Shrub	56.1±1.58	55.1±1.42	Y=0.981x-5.603	0.981	0.196
16	<i>Rauwolfia serpentina</i> (L.) Benth.	Shrub	36.9±1.69	38.8±1.64	Y=0.972x-0.732	0.928	0.841
17	<i>Tabernaemontana divaricata</i> (L.) R.Br.	Shrub	41.5±0.92	42.5±1.08	Y=0.774x+8.694	0.835	0.197
18	<i>Euphorbia leucocephala</i> Lotsy	Shrub	67.1±1.15	68.4±1.16	Y=0.900x+0.789	0.789	0.186
19	<i>Adathoda vesica</i> Nees	Shrub	40.9±1.21	39.4±1.21	Y=0.949x+0.986	0.996	0.330
20	<i>Cocculus hirsutus</i> (L.) Diels	Climber	23.8±0.87	23.3±0.75	Y=0.836x+3.363	0.952	0.061

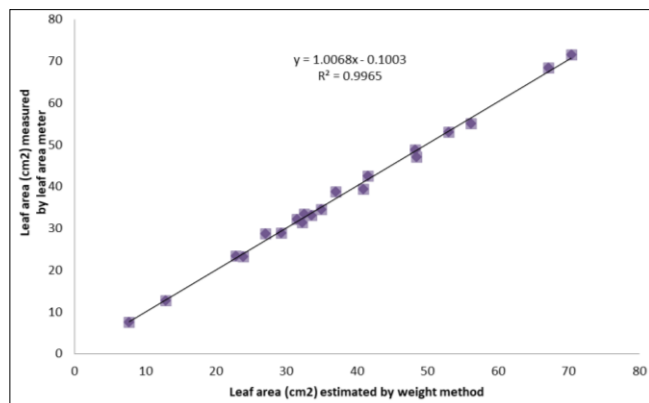


Fig 1: Relationship between leaf area of detached leaves measured by leaf area meter and that estimated by weight method across 20 plant species ($n = 200$).

Limit of present study

The present method is not suitable for those plants which have leaves irregularly thickened.

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Author contributions

PK designed and performed the experiment. PKP and PKK performed data analysis and drafted the manuscript. MLK contributed to the revision of the first draft. All authors have read and approved the final manuscript.

Conflict of interest

The authors do not have any conflict of interest concerning the publication of this manuscript.

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