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BIOMASS PREDICTION EQUATIONS FOR GIANT IPIL-IPIL [*LEUCAENA LEUCOCEPHALA* (LAM.) DE WIT]

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ABSTRACT

Aboveground biomass of 111 giant ipil-ipil trees with age 2-10 years from six provinces of the Philippines were determined to develop equations for estimating fresh and ovendry weight of the whole tree and its components.

Average ovendry weight of the total tree biomass ranged from 2.97 to 517.33 kg. The average tree contained 71.38 percent of the total dry weight in the merchantable bole, 3.45 in the foliage and 25.17 in the topwood, small and large branches and twigs.

Out of the seventeen regression models tested and evaluated for biomass estimation, an allometric model using two predictor variables provided the best estimates. Prediction equations based on this model and two others were derived in estimating fresh and ovendry weight of the whole tree and its components, viz., bole, topwood and large branches, stems and leaves.

Introduction

The current worldwide energy crisis has placed the less affluent nations to severe economic pressures. In an effort to remedy the situation, these countries have resorted to tapping what is available and preferably renewable energy sources, prominent of which is forest biomass. People turn to the forest to satisfy the demand for wood, causing great damage to the resource base and to the forest landscape in general. As a policy, maximum tree utilization was encouraged to alleviate the situation. What used to be wastes and residues, i.e., tops, branches, stumps and butt trimmings are now utilized for various productive purposes. For one, these are being used for generating power. They are likewise used as raw materials for pulp and paper, charcoal, and other products for industrial purposes. Lately, the leaves of some tree species, particularly ipil-ipil, are utilized as forage, leaf meal, and organic fertilizer to augment the shortage of animal feed and to cushion the high price of chemical fertilizers.

Over the great concern for the dwindling supply of wood, and the rate at which the forests are being exploited, establishment of industrial and energy forest plantations of fast growing species in the Philippines are being accelerated. Towards this end, however, accurate strategies for estimating the biomass values of these plantations for effective management as well as for commercial business transactions, would become a problem.

Now, since we are aiming for a 100% use for every tree we cut, reliable estimation of the different components is of paramount concern. The study developed biomass prediction equations for estimating fresh and ovendry weight of the merchantable wood, tops, branches and leaves of giant ipil-ipil. Weight, as the universally adopted measurement for quantifying biomass of all components, was used.

Methodology

The test plant: giant ipil-ipil

Leucaena leucocephala (Lam.) de Wit, locally known as giant ipil-ipil, astonishes thousands of people with its fast growth, multiple uses and adaptability to various site conditions. Among the fast-growing and high-yielding varieties that have been disseminated and known to thrive well in the Philippines are the Salvador type from Hawaii. These Hawaiian giants particularly those which have been identified for wood production like k-28 and k-8 have been widely used for tree planting projects in the Philippines in the last decade (Revilla and Gregorio, 1983).

Giant ipil-ipil grows on almost any type of soil but thrives best on well drained soils. It is adversely affected by strongly acidic soils, i.e. at pH below 5.5 (Tilo, 1977). It is very sensitive to phosphorous and calcium deficiency in soils (National Academy of Sciences, 1977). It grows best where annual rainfall ranges from 600-1700 mm and lowland areas mainly below 460 m above sea level.

According to Mendoza (1975), giant ipil-ipil can attain a height of 9.5 m with a diameter of 6 cm in 1½ years time. Within 8 years, it can reach 13 m in height and 37 cm in diameter (Benge, 1975).

On a per hectare basis, yields vary at different locations under different management systems, especially at different stand densities. On an average plantation site, the average annual growth rate is about 15 cu m/ha (over five years). On very good sites, it is more than 50 cu m/ha (Revilla and Gregorio, 1983).

In a survey by Kanazawa *et al.*, (1982) of nine giant ipil-ipil (k-8 variety) plantations in Northern Mindanao, biomass of each part varied widely, at 11-155 cu m/ha for stem volume, 6-78 tons/ha for stem dry weight, and 8-96 tons/ha for total above ground weight. The leaves ranged from 0.7 to 3.6 tons/ha dry weight.

Field procedures

The study covered six locations in the Philippines (Fig. 1) representing climatic types I and III of the corona climatic classification system. A total of 111 sample trees were taken from established giant ipil-ipil plantations (Table 1). The

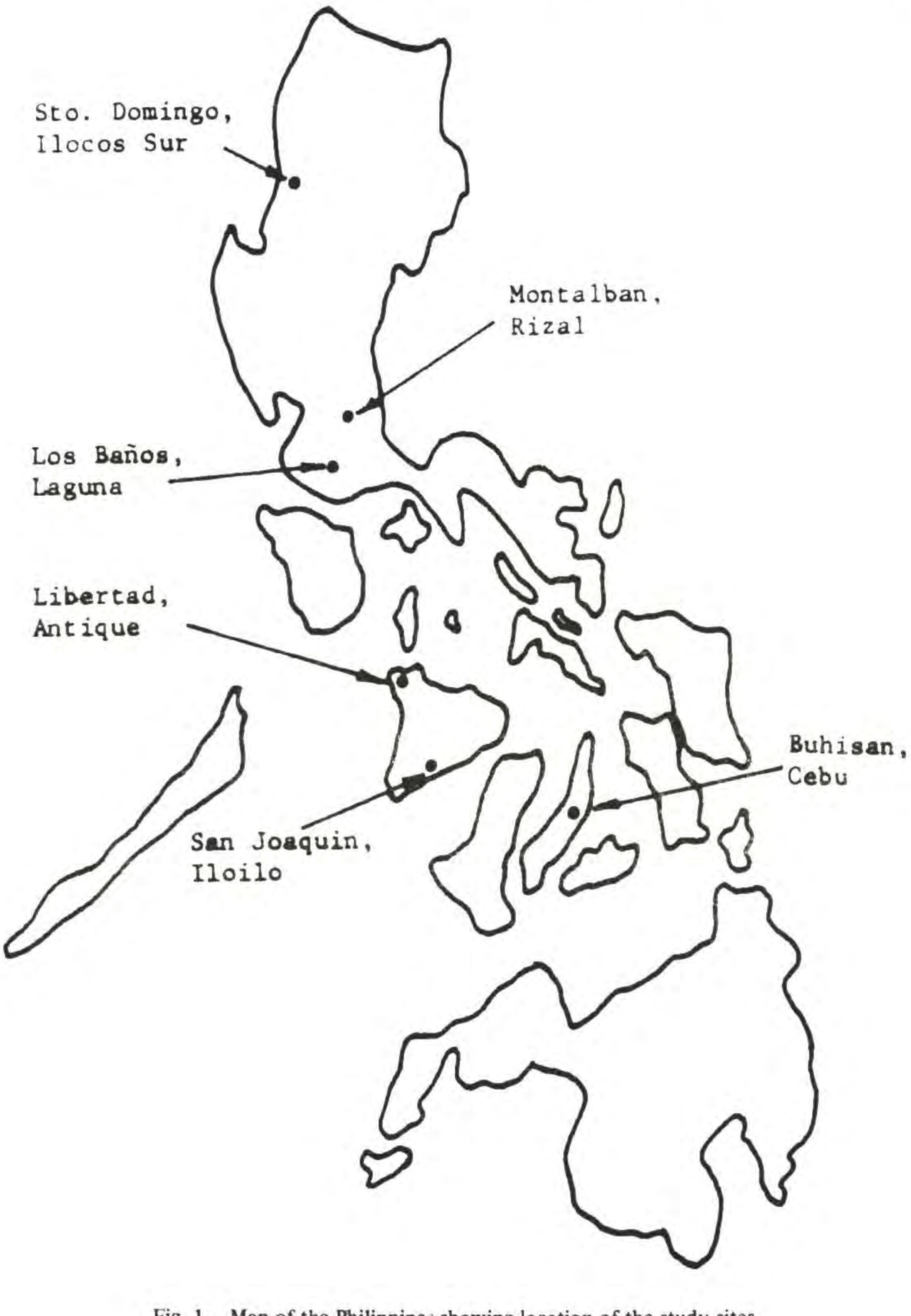


Fig. 1. Map of the Philippines showing location of the study sites.

Table 1. General description of the giant ipil-ipil stands in each location

CHARACTERISTICS		RIZAL	ANTIQUE	ILOCOS SUR	ILOILO	CEBU	LAGUNA
Age (Years)		2-4	4	7	5	10	9
Stand density (no. of trees/ hectares)	mean	8,926	10,742	8,140	648	1,500	459
	range	5,040-16,711	9,549-11,936	2,804-14,940	370-1,181	1.032-2,210	250-690
Mean Basal Area (m^2/ha)		16.60	22.59	45.62	22.53	90.25	9.89
Site index (BAGE 5 years)	mean	9.41	11.48	12.72	7.79	21.34	17.15
	range	3.33-12.18	9.42-11.70	11.36-14.18	5.84-9.00	10.60-25.60	13.73-20.49
Soil pH	mean	5.13	7.34	5.00	6.00	6.68	4.5
	range	4.90-5.80	6.60-7.65	4.90-5.10	5.50-6.60	6.40-7.10	4.2-4.8
Size of plantation (ha)		11.8	5.0	200.0	137.4	159.0	1.5

trees were felled about 15 cm above the ground, and measured for diameter at breast height (D), diameter at the base, diameter every 2 meters, merchantable height from the base to the minimum upper-stem diameter of 3 cm and total height. The trees were then cut into 2 sections from the base to the merchantable top. These were separated into components and weighed.

Disks of 3 to 5 cm thick were taken at the base of each section of the stem. These disks were labeled, sealed in plastic bags and taken to the Forest Research Institute (FORI) Laboratory for measurements. Samples of leaves (40-150 gm) and branches (10-200 gm) were likewise taken, labeled and sealed in plastic bags and brought to the laboratory.

Laboratory procedures

The fresh weight of the samples from the bole, branches and leaves were determined to the nearest 0.01 gm. All disk subsamples were debarked and weighed separately. The bark and wood from each disk as well as the sample branches were ovendried for 48 hours at 103° (±2°C) and then reweighed. On the other hand, the leaves were wrapped in aluminum foil, ovendried at 80°C to constant weight and then reweighed.

Disks collected from the boles were measured to calculate three ratios: (a) ovendry weight of disk to fresh weight of the disk (disk ODW/FW); (b) fresh weight of bark to fresh weight of the disk (bark FW/disk FW); and (c) ovendry weight of bark to fresh weight of disk (bark ODW/disk FW). Fresh weights of the sections were multiplied by ratios of appropriate disks to estimate ovendry weights. For each section, the average of the ratios calculated from disks collected at both ends of the section were computed and volume-weighted to obtain improved estimates. Estimated ovendry weight of sections were totalled to estimate bole wood weight and bole bark weight. For the uppermost segments, the ratios calculated from one disk were used to estimate ovendry weights. Ratio of fresh weight of bark to fresh weight of the disk was used to estimate fresh bark weights. The ovendry weights of branches were obtained by applying the corresponding ovendry/fresh weight ratios. The total ovendry weight of the leaves was obtained by multiplying the total fresh weight of the leaves by their sample ovendry/fresh weight ratio.

Statistical data on some of the measurements are shown in Table 2.

Analysis of data

Seventeen (17) regression models (Table 3) based on diameter breast height (D) and total height (H) were tested and evaluated for predicting biomass of each tree component.

The criteria used for selecting the "best" models and judging their suitability and/or fitness were as follows:

(a) highest coefficient of determination (R^2);
(b) smallest "index of fit" as proposed by Furnival (1961);
(c) how well the main assumptions underlying regression are satisfied;
(d) geometric reasonableness; and
(e) biological feasibility.

The coefficient of determination (R^2) was used initially to screen the 17 models. R^2 as the usual measure of goodness of fit is more suitable to compare equations that have the same dependent variable than when the dependent variables differ. In choosing between alternative models, Furnival (1961) however, recommended the use of likelihood comparisons rather than R^2 comparisons to evaluate the performance of several models including transformed or constrained models, e.g. logarithmic transformation or when the intercept (regression constant) is set to zero for estimating biomass. Accordingly, the logarithmic models not only assume multiplicative error term in the original power functions but its resulting R^2 in the standard way are in logarithmic scale. According to Furnival, these are not directly comparable with those obtained from the transformed models, hence his "index of goodness of fit" was used in the second screening.

For the "best" model which came out from the second screening, the main assumptions underlying regression, viz., homoscedasticity and normality were analyzed if they were really satisfied. In addition, the "best" model was examined

Table 2. Statistical data on diameter at breast height (D), total height (H), volume total green and ovendry mass of sample tree from the different study sites

CHARACTERISTICS	RIZAL	ANTIQUE	ILOCOS SUR	ILOILO	CEBU	LAGUNA
Sample Trees (No.)	27	13	18	14	21	18
D (cm)						
Mean	8.23	8.67	10.48	8.03	19.43	13.04
CV	0.464	0.345	0.436	0.310	0.333	0.370
Range	4.0-16.2	4.5-14.1	5.2-20.8	5.1-13.8	10.0-31.8	5.4-21.0
H (m)						
Mean	9.02	10.97	14.29	8.57	17.63	11.11
CV	0.330	0.167	0.248	0.192	0.204	0.275
Range	4.9-16.1	7.6-12.8	9.5-21.0	5.0-11.3	10.6-24.7	5.7-16.3
Volume (cu m)						
Mean	0.0379	0.0347	0.0705	0.0245	0.2272	0.0856
CV	0.998	0.680	1.096	0.774	0.633	0.736
Range	0.0032-0.1528	0.0075-0.0861	0.0115-0.2570	0.0047-0.0634	0.0359-0.5406	0.0076-0.2084
Total Green Biomass (kg)						
Mean	51.00	55.12	109.38	52.10	440.43	116.61
CV	1.096	0.708	1.168	0.818	0.680	0.752
Range	4.95-189.8	11.4-144.5	17.75-484.0	11.55-149.8	74.0-1,006.0	11-8-288.7
Total Ovendried Biomass (kg)						
Mean	29.45	24.28	67.23	26.78	243.51	60.12
CV	1.068	0.689	1.131	0.809	0.662	0.787
Range	2.97-98.01	6.99-78.89	10.10-270.30	5.73-73.02	33.88-517.33	5.84-145.32

if it ties into formulas for calculating volume (or weight) from lengths and diameters of cylinders, cones, paraboloids, etc. Lastly, the model was checked if it is biologically feasible. That is, if given a zero height or diameter, its predicted weight will not significantly differ from zero and if either D and H are increasing, its predicted weight will also be increasing.

Table 3. Regression models tested as possible candidates for tree and tree component weight equations

MODEL NO.	MODEL		REMARKS
1	$W = b_0(D^2H)^{b_1}$	or	$\ln(W) = \ln(b_0) + b_1\ln(D^2H)$
2	$W = b_1D^2H$		(No intercept)
3	$W = b_0 + b_1D^2H$		
4	$W = b_0 + b_1D^2H + b_2D^2H^2$		
5	$W = b_0D^{b_1}H^{b_2}$		$\ln(W) = \ln(b_0) + b_1\ln D + b_2\ln H$
6	$W = b_0 + b_1D$		(Simple linear model)
7	$\log(W) = b_0 + b_1D$		
8	$W = b_0 + b_1D^2$		(Basal area equation)
9	$W = b_0D^{b_1}$	or	$\ln(W) = \ln(b_0) + b_1\ln(D)$
10	$W = b_0 + b_1D + b_2D^2$		(Parabolic or quadratic model)
11	$W = b_0 + b_1D + b_2D^2 + b_3D^3$		(Cubic equation)
12	$\ln(W) = b_0 + b_1D + b_2H$		
13	$W = b_0 + b_1D^2 + b_2H + b_3D^2H$		
14	$W = b_0 + b_1D + b_2H + b_3D^2H + b_4D^2 + b_5D^3$		(Polynomial model)
15	$W = b_0e^{b_1D}$	or	$\ln(W) = \ln(b_0) + b_1D$ (Exponential Model)
16	$W = D/(b_1 + b_0D)$	or	$1/W = b_0 + b_1(1/D)$ (Hyperbolic equation)
17	$W/D^2H = b_0(1/D^2H) + b_1$		(Weighted model)

W = fresh or ovendry weight of tree or components (kg)
D = diameter at breast height (cm)
H = total tree height (m)
ln = natural logarithm
log = common logarithm
$b_0, b_1, b_2, b_3, b_4, b_5$ = regression coefficients

Results and Discussion

Out of the 17 regression models tested and evaluated, the allometric model

$$w = b_0 D^{b_1} H^{b_2}$$

where

w = fresh or ovendry weight of the whole tree or its components (kg)

D = diameter at breast height (cm)

H = total tree height (m)

b_0, b_1, b_2 = regression constants

provided the best estimates. Separate equations for fresh and ovendry weight of the whole tree and its components, regardless of location were derived from this "best" model (Table 4).

Among the tree components analyzed, weights of the bole were found to be generally predicted than the corresponding crown components. For giant ipil-ipil, the wood, bark, small branches and twigs, large branches and topwood and foliage comprised 67.14, 4.24, 5.61, 19.56 and 3.45 percent of total aboveground tree ovendry weight, respectively. Values for green weights are 60.45, 6.29, 5.98, 21.31 and 5.97 percent, respectively (Fig. 2).

The assumptions underlying regression of the above allometric model were checked by plotting the residuals (observed minus estimated values) around the fitted allometric model and by examining histograms of the residual errors. It was found that the model met the equality of variance and normality assumptions reasonably well. In addition to these checks, the estimated values over the observed values were plotted per study site to determine whether this model fitted the biomass data satisfactorily. It has been shown (Fig. 3) that the points closely gathered along the 45° line indicating that the model fitted the data quite well.

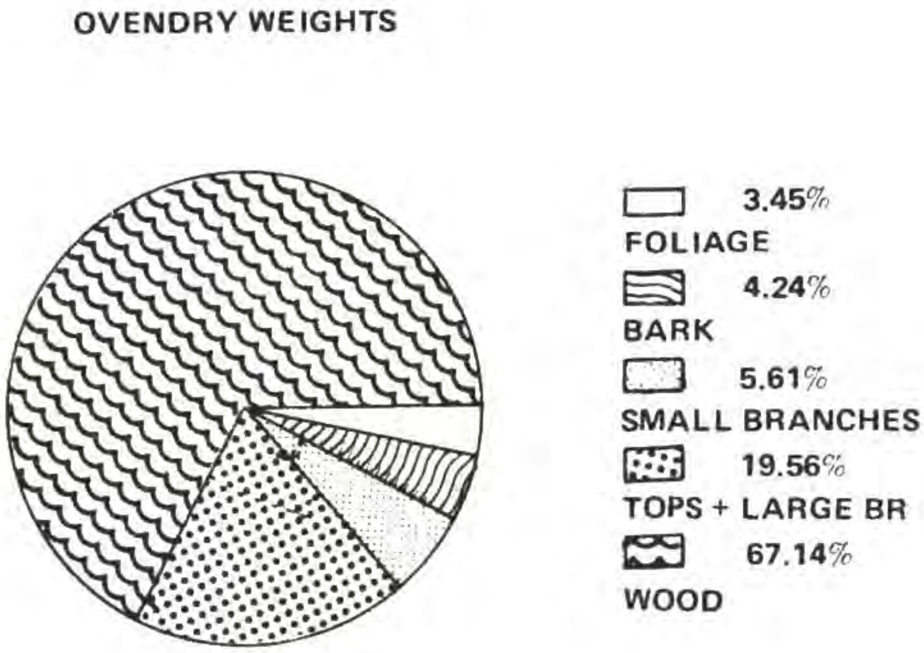
It is to be noted, however, that before the final equations were developed, the problem of underestimation of biomass estimates and non-additivity of component estimates accompanying the log-linear transformation of the allometric model, were corrected and solved, respectively.

The biases associated when transforming back the logarithmic estimates to their original units were removed by running the allometric model again, inserting b_1's and the b_2's from the first run, in the original model

$$w = b_0 D^{b_1} H^{b_2}$$

to obtain new and unbiased estimates of b_0 and consequently of the tree and component estimates.

The non-additivity of the component estimates (i.e., the predicted sum of the weights of component parts, based on individual equation for each part, being not exactly equal to the predicted total weight based on a single equation) was solved



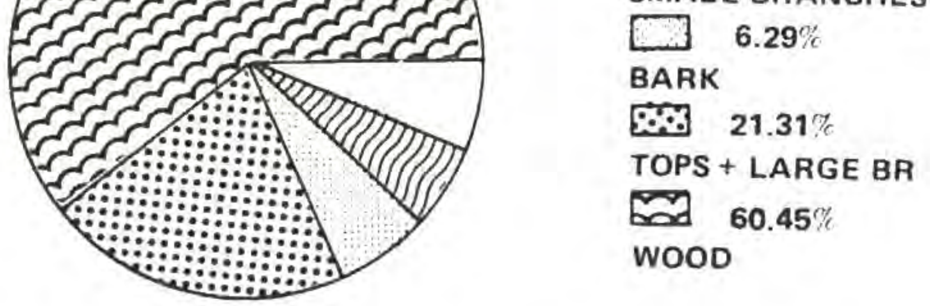


Fig. 2. Percent distribution of the different tree components.

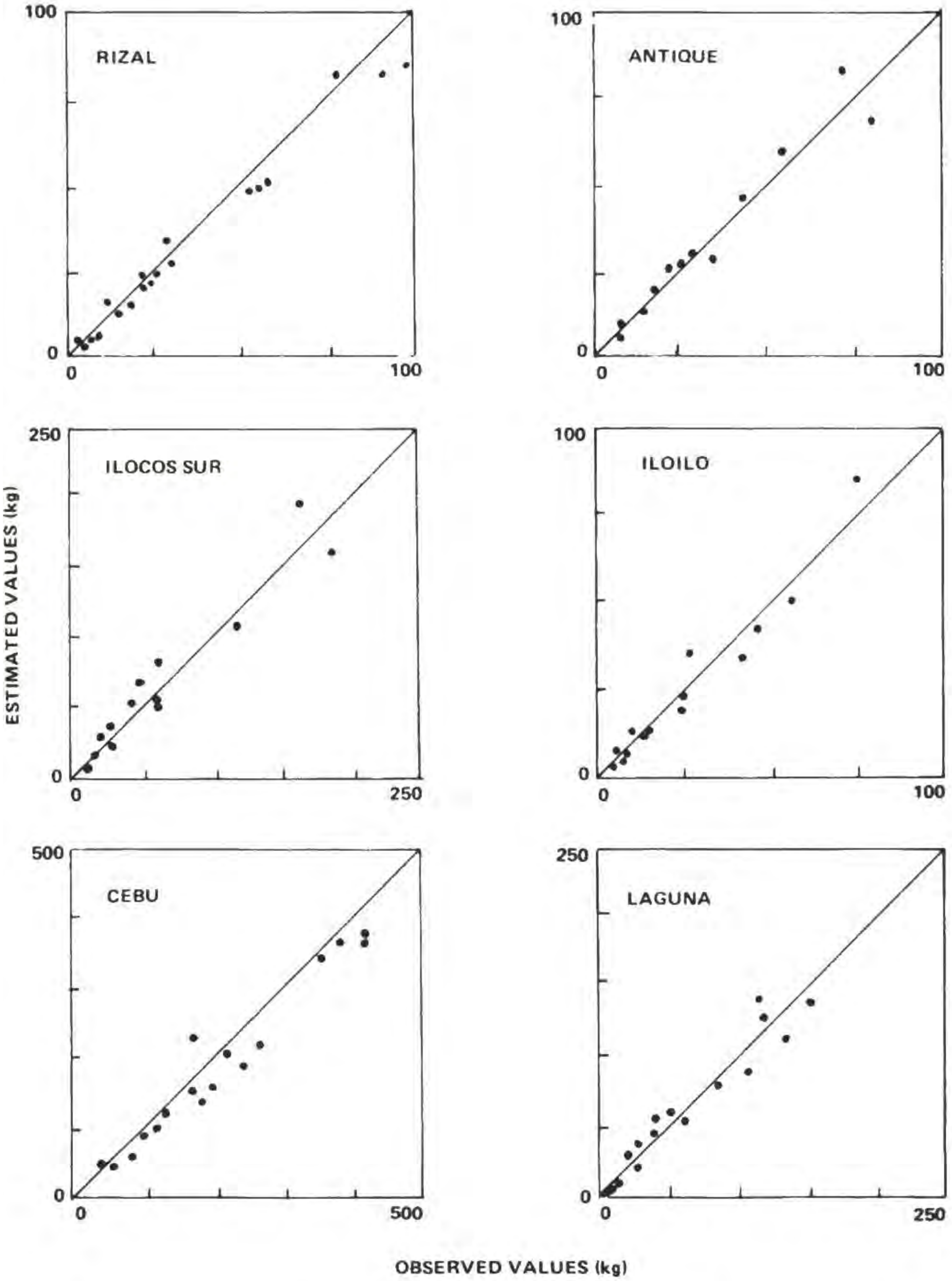


Fig. 3. Distribution of estimated values using Model 5 along 40° line in terms of total tree ovendry weight by location.

Table 4. Tree component weight regression coefficients for model $w = b_0 D^{b_1} H^{b_2}$

COMPONENT WEIGHTS (kg)	FIRST RUN				SECOND RUN			
	b_0	b_1	b_2	R^2	b_0	b_1	b_2	R^2
Fresh Weight								
Bole	−2.970	2.02	0.86	0.979	0.049730	2.02	0.86	0.937
Wood	−3.160	2.08	0.83	0.977	0.041644	2.08	0.83	0.936
Bark	−4.386	1.62	0.92	0.919	0.011548	1.62	0.92	0.798
Crown	−2.205	2.39	−0.10	0.907	0.140223	2.39	−0.10	0.920
Topwood and large branches	−5.328	3.09	0.14	0.864	0.005631	3.09	0.14	0.948
Small branches	−2.567	1.47	0.35	0.771	0.090488	1.47	0.35	0.862
Foliage	−2.242	1.95	−0.28	0.659	0.126849	1.95	−0.28	0.844
Whole Tree	−2.032	2.16	0.51	0.978	0.136561	2.16	0.51	0.977
Dry Weight								
Bole	−3.396	1.82	1.03	0.972	0.033760	1.82	1.03	0.955
Wood	−3.524	1.85	1.02	0.972	0.029525	1.85	1.03	0.953
Bark	−5.263	1.42	1.08	0.914	0.005745	1.42	1.08	0.943
Crown	−3.162	2.28	0.09	0.886	0.054459	2.28	0.09	0.913
Topwood and large branches	−5.884	2.94	0.25	0.858	0.003222	2.94	0.25	0.934
Small branches	−3.302	1.32	0.53	0.723	0.045140	1.32	0.53	0.839
Foliage	−3.426	1.85	−0.17	0.644	0.038815	1.85	−0.17	0.845
Whole Tree	−2.694	1.96	0.74	0.974	0.071563	1.96	0.74	0.973

by means of weighing using squares of the coefficient of variation imposed on the component equations. The component which is estimated with greater relative precision is given a lesser fraction of the discrepancy than with the other components. This allocation scheme was hold true to the bole as this was considered the largest and most important among the other tree components. Hence, since this part was given the least fraction of discrepancy, less distortion of its predictability was obtained.

Model $w = b_0 D^{b_1}$, which is also an allometric model, performed equally well as the "best" model for the bole and total tree biomass but was slightly weaker for predicting the crown components.

The polynomial model

$$w = b_0 + b_1 D + b_2 H + b_3 D^2 H + b_4 D^2 + b_5 D^3$$

was found to be nearly as good as the allometric models in predicting biomass of the whole tree and component parts of giant ipil-ipil. As a regression model for biomass estimation, it offers the following advantages:

(a) It is linear and thus, provides various combinations of predicted component estimates by simply adding the existing coefficients in the prediction equations;
(b) It gives direct biomass estimates, thus obviating the need for adjustments and corrections as when allometric functions are used;
(c) It is simple to understand and easy to use, since it has no transformations.

However, the model should not be used for predicting biomass of trees with diameter at breast height and total height outside the range covered by the samples in the study. Unlike the allometric models, there is no trend in the prediction using this polynomial model. The predicted weight beyond the ranges of D and H in this study, could be erratic and it could hardly be explained by this polynomial model.

Regression coefficients of the prediction equations obtained from the three models by location are listed in Tables 5 to 7, respectively. These tables provide information for the ovendry biomass aboveground tree components of giant ipil-ipil.

Conclusions and Recommendations

1. Biomass measurement is a necessary step towards complete-tree utilization. For giant ipil-ipil, information on leaf biomass is useful for leaf meal and organic fertilizer production while biomass information on the stem, topwood and branches are necessary for charcoal, fuelwood, pulp and paper manufacture.
2. Aboveground biomass of giant ipil-ipil can be obtained by using simple measurements such as diameter at breast height (D) and total height (H) of

the tree. Results of the study from six provinces strongly prove the suitability of the allometric model $w = b_0 D^{b_1} H^{b_2}$ in estimating biomass of the whole tree and component parts of giant ipil-ipil with ages 2-10 years old. It is within these areas, and with this range of ages (plantation), therefore, that this model is highly recommended for use.

The biomass prediction equations developed from this model, however, could also be applied in areas approximating the geographical and ecological conditions of the study sites especially within the same climatic type. For other areas or sites, preliminary testing is advisable.

3. Model $w = b_0 D^{b_1}$ which is also an allometric model, performed equally well for the bole and total tree biomass, but was slightly weaker for predicting the crown components.

   This model could be considered for situation where D is the only available tree attribute measured and for obtaining first-approximation estimates of a giant ipil-ipil stand.

4. The polynomial model

$$w = b_0 + b_1 D + b_2 H + b_3 D^2 H + b_4 D^2 + b_5 D^3$$

   was found to be nearly as good as the allometric models in predicting biomass of giant ipil-ipil. Although, it has five predictor variables and computationally tedious, it gives direct biomass estimates and a need for bias correction is totally eliminated as when allometric models are used.

   As the polynomial model is linear, there is no problem of additivity of components estimates. With these considerations and ease of application, this model could be used as a practical compromise for estimating biomass of giant ipil-ipil. However, predictions should be limited for diameters at breast height and total heights within the ranges covered by the samples in this study.

5. The general biomass prediction equations using the best model, i.e., $w = b_0 D^{b_1} H^{b_2}$ developed are valid for application in the areas within climatic types I and III across the six provinces studied. However, a slightly better fit may be possible by using the individual province equations also developed in this study.

6. Biomass estimation of the whole tree and component parts using tree weight equations has been amply demonstrated for giant ipil-ipil. The procedures used in this study, therefore, could also be tried to other fast growing species.

7. For pulp, paper and fuelwood purposes, tree biomass estimation especially for branches and tops is a better method than the usual practice of using volume estimation. For this reason, biomass estimation is highly recommended to attain maximum and efficient tree utilization.

8. For refinement of the models, it is recommended that future studies along this line should consider collecting additional biomass data possibly by region

from other giant ipil-ipil plantations throughout the country. As other data shall have been available, follow-up studies could also be conducted to determine variation of biomass estimation among different site conditions considering different climatic and edaphic factors.

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Table 5. Regression coefficients for model $W = b_0 D^{b_1} H^{b_2}$ by location and tree component in terms of dry weight

LOCATION/ COMPONENT	FIRST RUN				SECOND RUN			
	b_0	b_1	b_2	R^2	b_0	b_1	b_2	R^2
Rizal								
Bole	−2.820	1.84	0.74	0.977	0.057903	1.04	0.84	0.968
Wood	−2.979	1.87	0.76	0.977	0.049218	1.87	0.76	0.981
Bark	−4.395	1.40	0.64	0.948	0.012243	1.40	0.64	0.970
Crown	−3.535	2.61	−0.05	0.956	0.031938	2.61	−0.06	0.948
Topwood and large branches	−6.045	3.50	−0.33	0.767	0.003457	3.50	−0.33	0.913
Small branches	−4.456	1.64	0.83	0.821	0.011023	1.64	0.83	0.878
Foliage	−3.685	2.61	−0.70	0.853	0.026548	2.61	−0.70	0.889
Whole Tree	−2.414	2.09	0.49	0.984	0.089167	2.00	0.49	0.905
Antique								
Bole	−3.430	1.56	1.32	0.972	0.032114	1.56	1.32	0.993
Wood	−3.585	1.58	1.33	0.970	0.027477	1.50	1.33	0.992
Bark	−5.154	1.28	1.22	0.979	0.005776	1.28	1.22	0.998
Crown	−0.006	2.73	−1.61	0.902	1.140902	2.73	−1.61	0.852
Topwood and large branches	−4.126	3.60	−1.15	0.844	0.020680	3.66	−1.15	0.740
Small branches	0.672	1.94	−1.64	0.828	2.077099	1.94	−1.64	0.936
Foliage	−0.453	2.22	−1.58	0.832	0.000236	2.22	−1.58	0.721
Whole Tree	−1.773	1.95	0.41	0.900	0.167912	1.95	0.41	0.983
Ilocos Sur								
Bole	−2.673	2.13	0.49	0.945	0.457711	2.13	0.49	0.932
Wood	−2.773	2.17	0.46	0.940	0.067366	2.17	0.46	0.976
Bark	−5.029	1.74	0.78	0.881	0.007355	1.74	0.79	0.966
Crown	−2.773	2.01	0.16	0.806	0.070321	2.01	0.16	0.918
Topwood and large branches	−4.651	2.45	0.22	0.835	0.010041	2.45	0.22	0.894
Small branches	−3.118	1.37	0.60	0.853	0.005583	1.37	0.60	0.927
Foliage	−3.118	2.67	−1.00	0.801	0.051593	2.67	−1.00	0.938
Whole Tree	−2.112	2.13	0.38	0.965	0.129951	2.13	0.38	0.977

Table 5 (Continued)

LOCATION/ COMPONENT	FIRST RUN				SECOND RUN			
	b_0	b_1	b_2	R^2	b_0	b_1	b_2	R^2
Iloilo								
Bole	−4.422	2.17	1.14	0.961	0.011823	2.17	1.14	0.934
Wood	−4.566	2.23	1.11	0.961	0.010208	2.23	1.11	0.984
Bark	−6.170	1.47	1.43	0.951	0.002082	1.47	1.43	0.990
Crown	−3.445	2.67	0.04	0.841	0.029732	2.67	0.04	0.926
Topwood and large branches	−7.856	2.42	1.91	0.835	0.000356	2.42	1.91	0.927
Small branches	−3.956	2.29	0.07	0.688	0.018651	2.28	0.07	0.842
Foliage	−3.012	3.25	−1.37	0.742	0.041154	3.25	−1.37	0.768
Whole Tree	−3.314	2.31	0.74	0.953	0.035039	2.31	0.74	0.976
Cebu								
Bole	−2.613	1.93	0.67	0.937	0.069663	1.93	0.67	0.951
Wood	−2.739	1.94	0.68	0.934	0.051231	1.94	0.68	0.959
Bark	−4.356	2.03	0.30	0.671	0.007867	2.03	0.30	0.963
Crown	−2.705	2.69	−0.31	0.912	0.070671	2.69	−0.31	0.965
Topwood and large branches	−3.055	2.75	−0.47	0.881	0.050071	2.75	−0.47	0.955
Small branches	−4.486	2.11	0.13	0.851	0.013436	2.11	0.13	0.922
Foliage	−4.853	2.22	0.02	0.872	0.007430	2.22	0.02	0.937
Whole Tree	−2.032	2.13	0.38	0.964	0.127002	2.13	0.38	0.987
Laguna								
Bole	−3.218	2.11	0.59	0.966	0.40776	2.11	0.59	0.964
Wood	−3.375	2.15	0.58	0.966	0.034863	2.15	0.58	0.961
Bark	−4.083	1.61	0.70	0.944	0.007639	1.61	0.70	0.966
Crown	−2.610	2.25	−0.33	0.914	0.075885	2.25	−0.33	0.951
Topwood and large branches	−3.492	2.68	−0.58	0.889	0.031757	2.68	−0.58	0.944
Small branches	−2.958	1.31	0.12	0.700	0.052293	1.31	0.12	0.937
Foliage	−5.624	1.15	1.10	0.803	0.001005	1.15	1.10	0.899
Whole Tree	−2.457	2.13	0.36	0.973	0.087710	2.13	0.36	0.975

Table 6. Regression coefficients for Model $w = b_0 D^{b_1}$ by location and component. n = 111

LOCATION/COMPONENT	FIRST RUN			SECOND RUN		
	b_0	b_1	R^2	b_0	b_1	R^2
RIZAL						
Bole	−2.191	2.32	0.968	0.107886	2.32	0.984
Wood	−2.341	2.36	0.968	0.092588	2.36	0.984
Bark	−3.854	1.81	0.937	0.020973	1.81	0.970
Crown	−3.583	2.57	0.956	0.030189	2.57	0.946
Topwood and large branches	−6.345	3.29	0.766	0.002626	3.29	0.900
Small branches	−3.757	2.18	0.810	0.022453	2.18	0.904
Foliage	−4.273	2.16	0.845	0.015219	2.16	0.894
Whole Tree	−2.003	2.41	0.980	0.133935	2.41	0.909
ANTIQUE						
Bole	−1.095	1.94	0.900	0.327528	1.94	0.969
Wood	−1.235	1.97	0.900	0.284273	1.97	0.967
Bark	−3.001	1.63	0.893	0.049539	1.63	0.900
Crown	−2.858	2.26	0.830	0.067132	2.26	0.785
Topwood and large branches	−6.164	3.32	0.827	0.002694	3.32	0.689
Small branches	−2.233	1.47	0.682	0.117511	1.47	0.878
Foliage	−3.256	1.76	0.730	0.040404	1.76	0.844
Whole Tree	−1.045	2.07	0.973	0.346400	2.07	0.984
ILOCOS SUR						
Bole	−1.904	2.36	0.941	0.164764	2.36	0.975
Wood	−2.047	2.39	0.944	0.142361	2.39	0.974
Bark	−3.815	2.10	0.869	0.025619	2.10	0.959
Crown	−2.524	2.09	0.886	0.090859	2.09	0.919
Topwood and large branches	−4.313	2.55	0.834	0.014262	2.55	0.898
Small branches	−2.562	1.65	0.841	0.090408	1.65	0.902
Foliage	−4.156	2.16	0.780	0.009105	2.16	0.941
Whole Tree	−1.517	2.31	0.962	0.239943	2.31	0.977

Table 6 (Continued)

LOCATION/COMPONENT	FIRST RUN			SECOND RUN		
	b_0	b_1	R^2	b_0	b_1	R^2
ILOILO						
Bole	–3.050	2.69	0.916	0.046196	2.69	0.970
Wood	–3.231	2.74	0.920	0.038416	2.74	0.969
Bark	–4.450	2.12	0.846	0.011704	2.12	0.974
Crown	–3.399	2.68	0.841	0.031071	2.68	0.925
Topwood and large branches	–5.556	3.29	0.764	0.003539	3.29	0.942
Small branches	–3.869	2.31	0.688	0.020313	2.31	0.840
Foliage	–4.665	2.63	0.691	0.008349	2.63	0.815
Whole Tree	–2.421	2.65	0.933	0.084780	2.65	0.966
CEBU						
Bole	–1.294	2.13	0.910	0.256513	2.13	0.952
Wood	–1.383	2.14	0.905	0.233804	2.14	0.950
Bark	–4.257	2.12	0.667	0.014024	2.12	0.953
Crown	–3.322	2.49	0.907	0.038787	2.49	0.964
Topwood and large branches	–3.989	2.61	0.872	0.020560	2.61	0.955
Small branches	–4.201	2.15	0.850	0.016115	2.15	0.920
Foliage	–4.819	2.23	0.872	0.007689	2.23	0.937
Whole Tree	–1.287	2.24	0.956	0.264360	2.24	0.984
LAGUNA						
Bole	–2.706	2.47	0.954	0.067558	2.47	0.975
Wood	–2.868	2.50	0.955	0.057508	2.50	0.975
Bark	–4.279	2.03	0.921	0.013913	2.03	0.970
Crown	–2.898	2.06	0.909	0.057853	2.06	0.963
Topwood and large branches	–3.993	2.34	0.877	0.019959	2.34	0.946
Small branches	–2.851	1.38	0.699	0.058058	1.38	0.935
Foliage	–4.669	1.81	0.744	0.010147	1.81	0.847
Whole Tree	–2.143	2.35	0.968	0.119273	2.35	0.980

Table 7. Tree component weight ipil-ipil in 6 areas in terms of dry weight

COMPONENT DRY WEIGHT (kg)	REGRESSION STATISTICS						
	b_0	b_1	b_2	b_3	b_4	b_5	R^2
RIZAL							
Bole	−6.9877	−0.1035	1.4175	0.0013	0.0803	0.0074	0.98
Wood	−6.6844	0.0348	1.2715	0.0019	0.0595	0.0073	0.98
Bark	−0.3033	−0.1380	0.1460	−0.0006	0.0208	5.99E-5	0.94
Crown	20.3965	−10.7923	1.4512	−0.0144	1.2118	−0.0222	0.94
Topwood and large branches	18.2442	−9.0383	1.0421	−0.0104	0.9551	−0.0179	0.91
Small branches	0.4000	−1.7030	0.7558	−0.0053	0.0246	−0.0021	0.87
Foliage	1.7523	−0.0509	−0.3467	0.0014	0.0522	−0.0021	0.82
Total Tree	13.7121	−10.7573	2.7227	−0.o125	1.2714	0.0148	0.99
ANTIQUE							
Bole	−26.4859	12.0090	−0.4681	0.0435	1.4449	0.0349	0.98
Wood	−26.0617	11.9827	−0.5329	0.0419	−1.4490	0.0365	0.98
Bark	−0.4242	0.0264	0.0648	0.0015	0.0041	−0.0006	0.99
Crown	0.6052	−32.2033	9.1519	−0.1504	4.4592	−0.0644	0.95
Topwood and large branches	0.9911	−20.0974	7.4360	−0.1130	3.8850	−0.0655	0.93
Small branches	−0.5325	−3.4271	1.1382	−0.0223	0.5800	−0.0072	0.93
Foliage	−8.8534	1.3212	0.5770	−0.0143	−0.0057	0.0084	0.90
Total Tree	−25.4565	−16.2206	8.6190	−0.1085	3.0103	−0.0289	0.98

Table 7 (Continued)

COMPONENT DRY WEIGHT (kg)	REGRESSION STATISTICS						
	b_0	b_1	b_2	b_3	b_4	b_5	R^2
ILOCOS SUR							
Bole	47.0346	−10.8079	−0.8795	0.0134	1.0371	−0.0171	0.96
Wood	50.1668	−12.0752	−0.8200	0.0115	1.1539	−0.0203	0.96
Bark	−3.1323	1.2673	−0.0599	0.0019	−0.1169	0.0032	0.95
Crown	−33.6035	4.7967	1.9703	−0.0240	−0.3438	0.0359	0.93
Topwood and large branches	−20.5880	2.1008	1.3787	−0.0165	−0.1183	0.0207	0.89
Small branches	−10.9390	2.0496	0.5659	−0.0064	−0.1746	0.0122	0.96
Foliage	−2.0845	0.6463	0.0250	−0.0011	−0.0509	0.0031	0.93
Total Tree	16.5634	−7.2785	1.1500	−0.0125	08102	0.0156	0.96
ILOILO							
Bole	28.9467	−11.5943	0.0039	0.0185	1.4472	−0.0507	0.97
Wood	27.9954	−11.0679	−0.0695	0.0178	1.3753	−0.0481	0.96
Bark	0.9513	−0.5265	0.0634	0.0008	0.0719	−0.0026	0.97
Crown	85.9706	−34.0997	0.0302	−0.0157	4.3983	−0.1500	0.93
Topwood and large branches	34.6425	−16.3166	0.9985	−0.0269	2.1395	−0.0590	0.96
Small branches	20.9529	−7.0584	−0.4655	0.0081	0.8905	−0.0374	0.76
Foliage	30.3752	−10.7240	−0.5028	0.0030	1.3684	−0.0522	0.86
Total Tree	113.9660	−45.1676	−0.0293	0.0021	5.7736	−0.1981	0.97
CEBU							
Bole	275.5171	−56.8482	0.1185	0.0055	3.8917	−0.0687	0.94
Wood	263.8162	−54.6009	0.1111	0.0050	3.7435	−0.0561	0.94
Bark	11.7809	−2.2473	0.0074	0.0805	0.1481	−0.0025	0.91
Crown	−61.9108	14.8430	−1.3609	0.0014	−0.7769	0.0190	0.93

Table 7 (continued)

COMPONENT DRY WEIGHT (kg)	REGRESSION STATISTICS						
	b_0	b_1	b_2	b_3	b_4	b_5	R^2
Topwood and large branches	−95.5391	21.1854	−0,4103	0.0015	−1.1746	0.0250	0.93
Small branches	42.6088	−7.3580	0.0281	0.0005	0.4011	−0.0062	0.83
Foliage	8.9804	1.0156	0.0213	−0.0086	−0.0034	0.0002	0.88
Total Tree	201.9055	−39.7579	−1.2498	0.0063	2.9666	−0.0471	0.98
LAGUNA							
Bole	93.0811	−33.2136	4.0933	−0.0148	2.8101	−0.0527	0.95
Wood	88.6501	−31.5626	3.8644	−0.0142	2.6642	−0.0497	0.95
Bark	4.5310	−1.6511	0.2289	−0.0006	0.1469	−0.0030	0.93
Crown	13.1506	−3.2900	−0.2041	4.14E-5	0.3380	−0.0066	0.87
Topwood and large branches	14.2221	−3.7638	−0.1503	−0.0010	0.3557	−0.0065	0.88
Small branches	−1.7863	0.6361	−0.0483	0.0003	−0.0327	0.0005	0.71
Foliage	0.7149	−0.1620	−0.0065	0.0007	0.0150	−0.0006	0.75
Total Tree	101.7008	−34.8522	3.6602	−0.0142	3.0021	−0.0563	0.96