Allometric models for estimating the phytomass of a secondary Atlantic Forest area of southeastern Brazil

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Abstract: The purpose of this study was to develop and validate equations to estimate the aboveground phytomass of a 30 years old plot of Atlantic Forest. In two plots of 100 m^2, a total of 82 trees were cut down at ground level. For each tree, height and diameter were measured. Leaves and woody material were separated in order to determine their fresh weights in field conditions. Samples of each fraction were oven dried at 80 °C to constant weight to determine their dry weight. Tree data were divided into two random samples. One sample was used for the development of the regression equations, and the other for validation. The models were developed using single linear regression analysis, where the dependent variable was the dry mass, and the independent variables were height (h), diameter (d) and d^2h. The validation was carried out using Pearson correlation coefficient, paired *t*-Student test and standard error of estimation. The best equations to estimate aboveground phytomass were: lnDW = –3.068+2.522lnd (r^2 = 0.91; $s_{y/x}$ = 0.67) and lnDW = –3.676+0.951ln d^2h (r^2 = 0.94; $s_{y/x}$ = 0.56).
Keywords: *biomass, allometry, carbon, secondary Atlantic Forest, forest biomass estimation.*

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Resumo: O objetivo deste estudo foi desenvolver e validar modelos preditores para a fitomassa epigéa de uma área de Floresta Atlântica secundária. Em duas parcelas de 100m^2, 82 árvores foram cortadas, ao nível do solo, e anotadas suas medidas de altura e diâmetro. As folhas foram separadas dos ramos para determinação do massa fresca da porção foliar e lenhosa. Amostras de cada fração foram secas em estufa a 80 °C, até massa constante, para determinação do massa seca. As árvores foram distribuídas em duas amostras aleatórias, sendo uma utilizada para o desenvolvimento das equações de regressão, e a outra para validá-las. Os modelos foram desenvolvidos através da análise de regressão linear simples, tendo como variável dependente a massa seca (DW) e, como variáveis independentes a altura (h), o diâmetro (d) e o quadrado do diâmetro multiplicado pela altura (d^2h). A validação foi analisada através da comparação entre os valores obtidos em campo e os estimados pelas equações, através da análise de correlação intraclasse de Pearson e teste *t*-Sudent pareado. As melhores equações para estimar o massa seca das árvores foram: lnDW = –3,068+2,522lnd (r^2 = 0,91; $s_{y/x}$ = 0,67) e lnDW = –3,676+0,951ln d^2h (r^2 = 0,94; $s_{y/x}$ = 0,56).
Palavras-chave: *biomassa, alometria, regressão, Mata Atlântica, floresta secundária.*

Introduction

The Brazilian Atlantic Forests known as Mata Atlântica is the biome that recovered the Brazilian coast before the European colonization. The Atlantic Forest is a mosaic of ecosystems with a complex structure and hight biodiversity and endemism. The Atlantic Dominion includes dense tropical rain forest and areas of coastal flooded forest, lowland, submontane and montane forests. It taked up about 1.1million km^2 but today it is one of the most threaten biomes due to human activities as forest clearance for agriculture and pasture, construction of highways, mining and charcoal production. The forest remnants have survived in areas of difficult access (Joly et al. 1999). The restoration and preservation of these ecosystems can have a relevant role in the global carbon cycle. Knowledge about the biomass is necessary for the estimation of carbon reserves, which is currently very important and demanded for climate change issues.

Due to the large extension of the Brazilian territory, Brazil plays a significant role in the global carbon balance, accounting for 4 to 5% of total carbon emissions to the atmosphere, related to land use changes (Schroeder & Winjum 1995). However, the precision of estimates of C stores and of carbon fixation depends on the adequate estimates of the biomass for each type of ecosystem. Biomass is unusually measured directly in forest ecosystems due to the difficulties inherent in this type of study, such as its high cost and the need to cut the vegetation. Biomass estimations are based on predictive models that were previously developed on the basis of direct measurement using destructive methods. Specific models for the various ecosystems are necessary to minimize errorr in biomass estimates (Rochow 1974, McWillian et al. 1993).

Predictive models are elaborated based on regression analysis between tree mass (generally given in dry weight) and their dimensional data, such as height and diameter. Various types of regression models and different combinations of variables have been used in the development of predictive models of phytomass for tropical ecosystems (Folster et al. 1976, Golley et al. 1978, Saldarriaga et al. 1988, Brown et al. 1989, Overman et al. 1994, Moreira-Burger & Delitti 1999, Chave et al. 2001, Chave et al. 2005, Delitti et al. 2006. These models have been applied to quantify nutrient stores, accumulated organic material and potential carbon reserves, to determine vegetation growth rate after perturbation, and to identify determinants of variation in biomass.

The biomass of Atlantic forests has only been evaluated through indirect methods, using equations developed for other tropical forests. Delitti & Burger (1998) estimated the phytomass in various areas of the Atlantic Forest, testing 25 models developed for tropical forests using data from phyto-sociological surveys. Based on these studies, it was concluded that the Atlantic forest has a maximum accumulation of above-ground biomass of 350 $Mg.ha^{-1}$. Secondary and disturbed forests have less than 200 $Mg.ha^{-1}$, and in extreme cases of perturbation, the forests accumulate less than 100 $Mg.ha^{-1}$. However, the precision of the estimates of Atlantic Forest biomass can only be evaluated with the development of specific models, or the validation of models published for other tropical forests, through comparison with directly obtained data. This type of study is becoming increasingly difficult, as the Atlantic Forest, and its various physiognomies, are being reduced to areas protected by legislation. In this study, it was possible to take advantage of a rare opportunity to conduct a study of a destructive nature in this type of vegetative formation, due to the deforestation of portions of this vegetation that was undertaken to widen the Imigrantes highway, in the state of São Paulo. Due to their location inside the Serra do Mar State Park, and the difficult access, these portions were well-preserved forest a remnant was sampled for this study. Within this context, the objective of the study was to develop and validate predictive models for the above-ground phytomass of the Atlantic Forest.

Material and Methods

1. Study area

The study area is located at 23° 55’ 13’’ S and 46° 31’ 54’’ W in the Serra do Mar State Park, São Paulo, at an altitude of approximately 570 m. Field work was carried out in August 2000, in an area designated to be cleared for the construction of a highway descending from the Imigrantes Highway. Sampling was carried out in an area made available by the Imigrantes Consortium and closely followed the recommendations and limits established by the highway construction project.

The study area lies within the Atlantic Forest Domain, defined by Decree 750, February 10, 1993 (Brasil 1993). The vegetation is classified as Dense Ombrophylus or Tropical Pluvial, according to the classification of Veloso et al. (1991). Although it is a secondary forest area, vegetation was dense, with trees as tall as 30 m and overlapping canopies that restricted the penetration of sunlight into the understory. With a complex vertical structure, vegetation was composed of many species of bushes and trees distributed in various strata, as well as lichens, mosses, pteridophytes, vines, and epiphytes covering the larger trees. In the 1970s, the area was affected by the disposal of soil material extracted from the road construction causing tree fall and the perturbation of the original soil. After this perturbation, vegetation naturally recovered, therefore it could be considered as a secondary formation, approximately 30 years old.

Topography is rolling hills. According to the Parque Estadual da Serra do Mar soil map (Rossi & Pffeifer 1991), dominant soils are Alic Cambisols and Alic Red-yellow Latosols, with loamy texture.

The climate in the region is hot and moist. According to information provided by ECOVIAS, the company responsible for the operation of the highway, the mean annual temperature in the study area during the period 2000 to 2005 was 18.7 °C. The mean monthly temperature during the coldest month (August) was 16.1 °C, and of the hottest month (February), 20.8 °C. Data collected by the Departamento de Águas e Energia Elétrica - DAEE (1952 to 1996) at the pluviometric station nearest the study area (station E3-153, Curva da Onça) indicate a mean annual precipitation of 3,400 mm, and seasonal variation, with the lowest precipitation in winter (June to August). Mean monthly precipitation in the driest month (June) was 116 mm and in the moistest month (January) 441 mm.

2. Sampling and methods of analysis

Above-ground phytomass was measured using the destructive method (Whittaker et al. 1974, Chapman 1976, Golley et al. 1978), involving the cutting and weighing of all trees exceeding 1.5 m in height on two 10 x 10 m plots (100 m^2). In this area was harvest 82 trees whose height range from 1.9 to 27.9 m and diameter range between 1.6 and 47.8 cm.

Tree diameter was calculated from the measurement of perimeters breast height and at the base using a common measuring tape. Trees were cut at ground level using a chain saw, then heights were measured using a tape measure. Leaves were manually separated from the trunks and branches, and the fresh weight of each portion weighed with a manual scale to a precision of 200 g. From each tree, sub-samples were taken of a slice of trunk near the base, a portion of branches, and a portion of leaves, and were appropriately labeled.

All sub-samples collected in the field were taken to the laboratory, oven-dried (80 °C) until constant weight to determine water content and dry weight (kg) of each tree.

To develop and validate regression equations to estimate tree dry weight, the data on 82 trees collected from the two study plots were used. The trees were randomly separated into two independent samples composed of 41 trees each. One sample was used to develop the regression equations (sample 1), and the other to validate the equations (sample 2), as proposed by Snee (1977).

In this study, total dry weight (DW, kg) was used as the dependent variable and diameter (d, cm), height (h, m), and diameter squared times height (d^2h, cm^2m) as independent variables.

The variables were described using means, standard deviations, and maximum, minimum, and median values. Scatter diagrams were generated for all variables, using the original variables initially, then with the dependent variable transformed, next with the independent variables transformed, and finally, with all variables transformed. The scatter diagrams of the raw variables indicated that the model that adjusts well to these data is the power function. To obtain estimates of the parameters of the power function ($Y = aX^b$) natural logarithms were applied to the function ($\ln Y = \ln a + b \ln X$). The logarithmic transformation of the data stabilizes the effects of the increase in variance of the biomass with increasing tree size (heteroscedasticity) (Zar 1974), enabling the use of parametric statistical analyses, such as regression, in studies of this nature (Beauchamp & Olson 1973). The scatter diagrams of the transformed dependent variable and the transformed independent variables showed a linear relationship between them, indicating that a linear regression could be adjusted to the transformed values (Vieira 2004). Various models have been developed for tropical forests employing linear regression analysis with logarithmic transformation of the data (Jordan & Uhl 1978, Saldarriaga et al. 1988, Brown et al. 1989, Martinez-Yrizar et al. 1992, Scatena et al. 1993, Overman et al. 1994, Santos 1996, Higuchi et al. 1998). Thus, in the modeling process for this study, only transformed data was used for both variables.

Pearson's correlation analysis was conducted on the variables. To increase the precision of the phytomass estimates, different variables can be introduced into the regression equation as long as there is no co-linearity among them. The high correlation between the variables makes it impossible to separate the effects of the independent variables on the dependent variable in a multiple regression analysis. Several authors reported high correlation between tree diameter and height, and above-ground biomass (Jordan & Uhl 1978, Overman et al. 1994). Thus, the equations were obtained through simple linear regression analysis, after testing co-linearity between selected variables. Linear regression analysis was applied on the dependent and independent variables that presented a linear relationship, identified in the scatter diagrams. The models that showed bias in the analysis of the residuals were excluded.

In the second stage, validation analysis of the equations was carried out. Using the data from sample 2, Student's paired *t*-test was applied to compare the means of the real values obtained in the field survey to those estimated using the equations. Pearson's intra-class correlation coefficient (r_{icc}) was also calculated for comparison of the real values and those estimated by the equations.

Following these phases of modeling and validation, the most appropriate models were defined using the following selection criteria: highest coefficients of determination (r^2), lowest standard errors of the estimates ($s_{y/x}$), highest intra-class correlation coefficients (r_{icc}) found in the validation, greater similarity of means, and 95% confidence intervals between the real values and those estimated using the equations, according to visual analysis and the application of the model.

In the final stage, simple regression analysis was done using all the data from all the trees sampled (n = 82), with the independent variables being the predictor variables in the models developed, validated, and selected in the first phase of the study. The criteria for selecting the best model were the highest determination coefficient, standard deviation, and better residuals distribution.

Available models in the literature were validated for the sudied vegetation, through the comparison between estimated biomass for sample 2 trees and the values obtained in the field.A significance level of 5% was used in all the analyses. All statistical analyses (descriptive analysis, correlation analysis, simple and multiple regression analyses) were carried out using *Statistica* for Windows® (version 6.0) and *Statistical Package for the Social Sciences* (SPSS) for Windows® (version 8).

Results

The equations from the first step in the work were developed using sample 1 data, which was composed of 41 trees with diameters, varying from 1.6 to 47.8 cm, with a mean of 8.5 cm. The height of trees varied between 2.3 to 27.9 m, with a mean of 7.0 m. Distribution parameters of the variables used in the study are presented in Table 1. Notice that the median values are generally close to the means, with the exception of dry weight (lnDW).

The matrix of the Pearson's linear correlations among all the variables (Table 2) shows a strong correlation between the independent variables, as reported in similar studies (Overman et al. 1994).

The models resulting from the simple linear regression analysis are presented in Table 3. All are statistically significant ($p < 0.001$), as can be observed by the confidence interval of the regression coefficient ($CI_{95\%}$ b) of each model. Analysis of residuals for the equations showed that the errors presented a normal distribution and no bias.

In the validation of the equations, the data from sample 2 were used. This was composed of 41 trees with heights varying between

Table 2. Matrix of the Pearson's linear correlations among the variables used in the modeling process.

Tabela 2. Matriz de correlação linear de Pearson entre as variáveis utilizadas no processo de modelagem.

Variables	ln(DW)	ln(d)	ln(h)	ln(d^2h)
ln(DW)	1.00	0.97	0.96	0.97
ln(d)	-	1.00	0.95	1.00
ln(h)	-	-	1.00	0.97
ln(d^2h)	-	-	-	1.00

$p < 0.001$

Table 1. Distribution parameters of the variables used in the study, referring to sample 1, used in the development of the predictive models (n = 41).

Tabela 1. Parâmetros de distribuição das variáveis de estudo, referentes a amostra 1, utilizada no desenvolvimento dos modelos preditores (n = 41).

Variables	Mean (sd)	Minimum	Maximum	Median
lnDW (kg)	1.2 (2.4)	–2.5	7.8	0.5
ln d (cm)	1.7 (0.9)	0.5	3.9	1.5
ln h (m)	1.7 (0.6)	0.8	3.3	1.5
ln d^2h (cm^2m)	5.1 (2.4)	2.1	11.1	4.4

n = number of trees used in the modeling process; sd = standard deviation; d = diameter (cm); DW = dry weight (kg); h = height (m).

Table 3. Description of the models elaborated using simple linear regression, with the Natural logarithm of dry weight (lnDW) in kilograms (kg) as the dependent variable.

Tabela 3. Descrição dos modelos elaborados através da análise de regressão linear simples, tendo como variável dependente o logarítmo neperiano da massa seca (lnDW) em quilogramas (kg).

Predictor variable	a (sd)	b (sd)	$s_{y/x}$	$CI_{95\%}$ b	r^2	F
ln d (cm)	–3.217 (0.215)	2.562 (0.112)	0.632	[2.335; 2.789]	0.931	522.4
ln h (m)	–5.041 (0.310)	3.591 (0.169)	0.675	[3.250; 3.933]	0.921	451.9
ln d^2h (cm^2 m)	–3.794 (0.206)	0.964 (0.037)	0.552	[0.890; 1.037]	0.947	696.7

$p < 0.001$; a = constant of the equation or linear coefficient of the line; b = regression coefficient; sd = standard deviation; CI = confidence interval; r^2 = coefficient of determination; F statistic; $s_{y/x}$ = standard error.

Table 4. Pearson's intra-class correlations coefficient (r_{icc}) among the means of the dry weights of the trees in sample 2, obtained from the equations developed, and the real means obtained in the field. Results of Student's paired *t*-test (p) comparing real dry weight of the trees in sample 2 and the dry weight estimated by the equations.

Tabela 4. Índice de correlação intraclasse de Pearson (r_{icc}) entre as médias de massa seca das árvores da amostra 2, obtidas pelas equações desenvolvidas, e os valores médios reais, obtidos em campo. Resultado do teste *t*-Student pareado (p) para comparação entre a massa seca real das árvores da amostra 2 e a massa seca estimada pelas equações.

Description of the model	Validation					
Equation	$r_{icc\ (p<0.001)}$	p	Mean (sd)	Median	Min.-Max.	25-75 (%)
Field	-	-	27.27 (77.97)	2.09	0.08-421.73	0.70-6.40
lnDW = –3.2169 + 2.5620 ln(d)	0.854	0.29	18.94 (38.67)	2.20	0.13-145.35	0.59-9.00
lnDW = –5.0406 + 3.5914 ln(h)	0.868	0.69	24.86 (63.50)	2.76	0.06-338.43	0.58-12.38
lnDW = –3.7961 + 0.9636 ln(d2h)	0.908	0.33	20.80 (44.02)	2.11	0.17-170.44	0.54-10.14

DW = dry weight (kg); d = diameter (cm), h = height (m), p = descriptive level of Student's paired *t*-test; r_{icc} = Pearson's intra-class correlation coefficient.

Table 5. Description of the final models elaborated using simple linear regression analysis, based on the total number of trees sampled (n = 82), with Natural logarithm of dry weight (lnDW) in kilograms (kg) as the dependent variable.

Tabela 5. Descrição dos modelos finais elaborados através da análise de regressão linear simples, a partir do total de árvores amostradas (n = 82), tendo como variável dependente o logarítmo neperiano da massa seca (lnDW) em quilogramas (kg).

Predictor variable	a (sd)	b (sd)	$s_{y/x}$	$CI_{95\%}$ b	r^2	F
ln d (cm)	–3.068 (0.167)	2.522 (0.091)	0.672	[2.342; 2.703]	0.906	773.3
ln h (m)	–4.707 (0.236)	3.384 (0.130)	0.714	[3.124; 3.643]	0.894	675.5
ln d^2h (cm^2 m)	–3.676 (0.153)	0.951 (0.028)	0.558	[0.896; 1.007]	0.935	1157.3

$p < 0.001$; a = constant of the equation or linear coefficient of the straight line; b = regression coefficient; sd = standard deviation; CI = confidence interval; r^2 = coefficient of determination; F statistic; $s_{y/x}$ = standard error.

1.9 m and 20.6 m, with a mean of 6.6 m. The mean diameter was 7.4 cm, varying from 1.6 to 24.5 cm.

Estimated biomass values from the models did not significantly differ from expected values (Figure 1, Table 4). All the models presented high intra-class correlation coefficient (r_{icc}). Student's paired t-test indicated no significant differences between the means of the estimated dry weights for the trees and those found in the field (Table 4). In spite all models were satisfactory, no sufficient data are available to to discriminate between them.

Considering that the variables used generated models appropriate for estimating phytomass of the Atlantic Forest, the final models were adjusted through simple linear regression analysis using all the information from all the trees collected (n = 82) in the field (Table 5). Despite being very similar to those developed using sample 1, they reflect all the variation in the dimensions of the trees represented in this study. Mean height of the 82 trees was 6.8 m, ranging from 1.9 to 27.9 m. Mean diameter was 8.0 cm, ranging between 1.6 and 47.8 cm. The equations were statistically significant ($p < 0.001$) and showed no tendencies in the analysis of residuals. The model with height as the predictor variable presented the lowest coefficient of determination and the largest standard error of the estimate. Considering the criteria established, the models whose predictor variables were diameter (lnDW = –3.068+2.522lnd) and diameter squared times height (lnDW = –3.676+0.951ln d^2h) were considered to be predictors of above-ground phytomass in the Atlantic Forest under conditions similar to those found in the local study.

Table 6 shows a validation of models selected from the literature. Estimated dry weight for trees of sample 2, when calculated using equations developed for secundary wet forests (Scatena et al. 1993; Brown et al. 1989) or primary wet forests (Chave et al. 2001, Overman et al. 1994), were not statistically different from the real mean. However, they significantly differed when the used equations were developed for moist forests.

Discussion

Two models were considered as good predictors for phytomass of *Mata Atlântica*: ln DW = –3.068+2.522lnd and lnDW = –3.676+0.951lnd^2h. The first one has the advantage of only requireing one variable, diameter that is easily measured in the field and less subjected to sampling errors. The second model adds the requirement of tree height which is not always available in forest samplings owing to the difficulty of getting accurate measurements. In spite of this limitation, this equation could be considered appropriate to estimate

Table 6. Pearson's intra-class correlations coefficient (r_{icc}) among the means of the dry weights of the trees in sample 2, obtained from the equations from the literature and the real means obtained in the field. Results of Student's paired *t*-test (p) comparing real dry weight of the trees in sample 2 and the dry weight estimated by the equations.

Tabela 6. Índice de correlação intraclasse de Pearson (r_{icc}) entre as médias de massa seca das árvores da amostra 2 obtidos pelas equações da literatura e os valores médios reais, obtidos em campo. Resultado do teste *t*-Student pareado (p) para comparação entre a massa seca real das árvores da amostra 2 e a massa seca estimada pelas equações.

Description of the model		Validation					
Equation	Life zone (*)	$r_{icc\ (p<0.001)}$	p	Mean (sd)	Median	Min-Max	25-75 (%)
Field	W	-	-	27.27 (77.97)	2.09	0.08-421.73	0.70-6.40
[1]lnDW = –2.39+2.48 ln(d)	W	0.852	0.35	33.35 (66.60)	4.35	0.29-249.31	1.23-16.97
[2]lnDW = –2.14+2.41 ln(d)	W	0.850	0.20	35.83 (70.30)	5.09	0.36-262.37	1.49-19.17
[3]lnDW = –3.30+0.94 ln(d^2h)	W	0.906	0.77	28.87 (60.32)	3.15	0.27-232.84	0.84-14.67
[1]lnDW = –3.28+0.95 ln(d^2h)	W	0.907	0.48	30.99 (65.01)	3.30	0.28-251.17	0.87-15.55
[4]lnDW = –3.84+1.04 ln(d^2h)	W	0.915	0.08	36.50 (80.57)	2.81	0.19-315.21	0.66-15.21
[2]lnDW = –2.19+2.54 ln(d)	M	0.853	0.01	49.62 (100.74)	5.93	0.36-378.29	1.62-24.0
[5]lnFW = –1.49+2.55ln(d)	M	0.854	0.01	49.76 (101.23)	5.89	0.36-380.27	1.60-23.92
[3]lnDW = –3.11+0.97 ln(d^2h)	M	0.909	0.01	44.14 (93.90)	4.33	0.34-636.97	1.11-21.13

[1](Scatena et al. 1993), [2](Chave et al. 2001), [3](Brown et al. 1989), [4](Overman et al. 1994), [5](Higushi et al. 1998)
DW = dry weight (kg); FW = fresh weight (kg); d = diameter (cm), h = height (m), p = descriptive level of Student's paired *t*-test; r_{icc} = Pearson's intra-class correlation coefficient; W = wet life zone; M = moist life zone; (DW = 0.49FW), (*) the same criteria used by Chave et al. 2005.

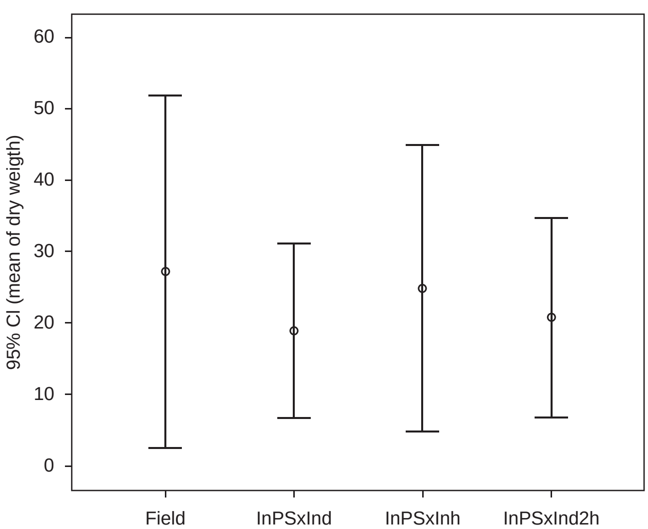

Figure 1. Means of dry weights (kg) and respective 95% confidence intervals (CI), according to the estimates resulting from the equations developed in this study, applied to sample 2.

Figura 1. Médias de massa seca (kg) e respectivos intervalos de 95% de confiança (CI), segundo as estimativas das equações desenvolvidas neste estudo, aplicadas na amostra 2.

Mata Atlântica phytomass for similar conditions as those of the study area, owing to the fact of its showed the highest determination coefficient ($r^2 = 0.935$) and the lowest standard error.

Further to tree size defined by its height and diameter, other factors should be considered in phytomass estimations. In this study, we validated models available in the literature that used height and diameter as predicting variables, similar to those developed in the sampled forest. Validation results indicate that model application should consider forest type (dry, moist or wet) for which the model was developed. In spite that forest type is not the major factor in determining the quantity of accumulated organic matter by trees, forest type has influence in allometric relationships (Brown et al. 1989, Chave et al. 2005). Developed models for moist life zones (Chave et al. 2001 and Higushi et al. 1998) produced higher estimates of tree dry weight for sample 2 trees, and therefore were not appropriated for the study area. According to Brown at al. (1989), for a given diameter, moist life zone trees show higher biomass than wet life zone because they tend to be taller. Therefore, moist life zone equations tend to over-estimate biomass in other forest types.

In the next step, this research would investigate the influence of wood density in the determination of biomass for Mata Atlântica trees. Chave et al. (2005) considered that tree diameter is the most relevant variable for predicting biomass in tropical forests, followed by wood density. The large species richness and the lack of knowledge of wood density for tropical forest trees would difficult wood density use. However, Chave et al. (2006) indicated that the identification of tress at the genus level would be enough for using wood density in predicting models. New studies in the various Mata Atlântica formations should include that variable, in the perspective of increasing biomass estimates accuracy.

Conclusions

The models developed and validated in this study explain about 90% of the variance in the dry weight (kg) of the trees, which generates a good estimate of this ecosystem descriptor. Information contained in different forest surveys, such as height and diameter of trees, can be used to estimate biomass. In spite of the limitations, and taking in account it is a secondary forest area, this information can contribute to estimates of carbon stores and exchanges, illustrating the role of the Atlantic Forests in the global carbon balance, as well as providing the basis for decisions regarding the management and recovery of these ecosystems.

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