Aboveground Biomass Allometric Model Development for Cashew in Cameroon

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ABSTRACT

The study's goals were to develop biomass equations for cashew plantation in Cameroon. A total of 60 cashew trees were measured within 30 were destructively sampled to determine biomass content in tree components. The regression equations relate AGB with DBH and height (H) were computed and the models were tested for accuracy based on observed data. The best model was selected based on higher adj R^2 and lower Akaike information criterion than rejected models. The relations for all selected models are significant ($p<0.000$), which showed strong correlation AGB with selected dendrometric variables. The fit of the allometric biomass models AGB is Ln (AGB)=4.66+0.28 × Ln (D). The specic allometeric equation is developed for cashew which can be used in similar ecosystem in Cameroon for the implementation of Reduced Emission from Deforestation and Degradation (REDD+) activities to benefit the local communities from carbon trade.

Keywords: Aboveground biomass; Allometric model; Cashew; REDD+

INTRODUCTION

Biomass estimation of tropical forest is crucial for understanding the role of terrestrial ecosystems to the carbon cycle and climate change mitigation [1,2]. To implement mitigating policies and taking the advantage of the Reducing Emissions from Deforestation and Forest Degradation (REDD+) needs well valid estimates of forest carbon stocks [3]. Under the United Nations Framework Convention on Climate Change (UNFCCC), countries have to report regularly the state of their forest resources through assessments of carbon stocks based on forest inventory data and allometric equations [4]. The allometric equation, estimates the whole or partial mass of a tree from measurable tree dimensions, including trunk diameter, height, wood density, or their combination [5-7]. The most common allometric model used to predict biomass is the power function Y=a × Xb, where Y, dry biomass weight, a is the integration factor, b is the scaling factor and X is the diameter at breast height [8]. This function is considered as the best applicable mathematical model for biomass studies because the growing plants maintain the different mass proportion between different parts [9].

The cashew tree (*Anacardium occidentale*) is a crop of tropical nuts belonging to the Anacardiaceae family, known for having a resinous bark and often caustic oils in the leaves, barks and fruits. It plays an important role in the socio-economic, ecological, cultural, agronomic and pastoral fields for the populations [10, 11]. Cashew appears today as a strategic crop whose prospects for development and guaranteeing income for sustainable diversification of holdings are very promising [12]. In order to mitigate climate variability and change, the international community has adopted a number of decisions such as those relating to reducing emissions from deforestation and forest degradation, sustainable management of forest, conservation and enhancement of forest carbon stocks known as REDD+ activities [13].

Allometric biomass equations have been developed for tree species in different ecological regions of the world, which are related to species-specific and stand-specific biomass models [14]. Allometric equations which are regressions linking the biomass to some independent variables such as diameter, height and wood density are used to estimate tree components from the forest [15]. However, in tropical forests, the accurate estimates of carbon sequestration are lacking due to a scarcity of appropriate allometeric models. In Cameroon, were conducted to establish allometric models for estimating biomass for high socio-economic and environmental importance species (*Boscia senegalensis, Daniella oliveri, Faidherbia albida, Moringa oleifera*) [16-19]. However, no study was specifically interested to develop allometric models for estimating the biomass of cashew. Hence the objective of this study is to develop allometric models for predicting above biomass of cashew in Cameroon.

MATERIALS AND METHODS

Data collection

The study took place in Cameroon, more precisely in the North region. This region is located between 8° to 10° N latitude and 12° to 16° E longitude. The average annual rainfall of 1003 mm and an average annual temperature of 28.95°C [20].

Destructive method was used to determine the biomass of each individual tree. Based on the method described a total of 60 cashew trees were measured within 30 were destructively sampled to determine biomass content in tree components [8]. Selection of each individual tree was based on diameter at breast height. The individuals were grouped into four DBH classes: 5-15, 15-25, 25-35, 35-45, and 45-55 cm. For each sample tree the DBH and total

Height (H) of the stand trees were first recorded. Trees were felled close to ground level. The trees were selected to ensure a representative distribution of diameter classes within the sampling plots. Individuals were selected on the basis of their availability and absence of human exploitation or disease. Before the trees were felled, the diameters of the individuals with bark were determined using a tape and the total height was determined using a clinometer. The individuals were then cut 5 cm from the ground using a chainsaw and divided into compartments: The leaves, branches and stems. The different compartments, stems, branches and leaves were weighed using a 150 kg capacity scale after which the total wet weight of each compartment of the tree was determined in the field. The stems and large branches were cut into small pieces and bags and green weight with a scale on the field.

In the laboratory, a sample from each compartment was taken and dried in an oven for 48 hours, at a temperature of 70°C for the leaves and 105°C for the samples of stem and branch [21] (Figure 1).

Figure 1. Destructive method. (A) Measurement of variables; (B) Cutting of the tree; (C) Separation of the component; (D) Separation of the sheet for the branch; (E) Difference of the compartment; (F) Weighing of the leaf; (G) Branch weighing; (H) Stem weighing; (I) Compartment aliquots; (J and K) Aliquot weighing; (L) Drying of aliquots in the oven.

Statistical analysis

We used the power model to develop the equations biomass for AGB of cashew: Y=a × Xb. The following three models were considered for estimating AGB from variables (DBH and H) and coefficients of regression (a, b, c) [8]:

Ln (AGB)=a+b × Ln (DBH) .... (1)

Ln (AGB)=a+b × Ln (DBH2 × H) .... (2)

Ln (AGB)=a+b × Ln (DBH)+c × ln (H) ....(3)

Two criteria were used to test the robustness and precision of AGB. They are in order of importance: Adjusted coefficient of determination (adj R^2= (1-SRS)/STS where STS: Sum of Total Squares and SRS: Sum of Residual Squares [8]. AIC or Akaike information criterion obtained by the following formula: AIC=-2ln (L)+2p (L “Likelihood” or Probability at which the predicted model is correct to the unknown true and p: Total number of parameters of the model) [22].

The arithmetic tests previously listed proved insufficient to control the quality of a constructed model [23]. Considered that the visual examination and the qualitative behavior of the residues are essential for deciding on the validation and consistency of the models. These additional tests are presented as follows: As part of a regression or smoothing process, can visualize the Henry's line of the residuals to ensure that their distribution does not stray too far from a normal distribution. It also makes it possible to detect possible outliers. The shapiro-wilk test was performed to verify the best models at the probability threshold of 5% [1]. It is a graphical representation in the form of a point cloud of the residuals according to the forecasts. It makes it possible to assess the divergence of the predicted values around the line representative of zero residues [1]. For an acceptable divergence, the point cloud forms a homogeneous mass around the line of zero residues. Bartlett’s test was performed to verify the consistency of the residuals at the 5% probability level. We used R software for the analysis.

RESULTS

Distribution of dendrometric variables and AGB

DBH varies from 5.41-52.54 cm with mean 35.81 cm. Height varies from 2.10-13.50 m with mean 9.04 m. AGB varies from 163.23 to 296.29 kg with mean 256 kg (Table 1).

Relationships of AGB with DBH and H

AGB was significantly correlated only with DBH. So the AGB was no significantly correlated only with H (Table 1).

Table 1. Distribution of dendrometric variables and AGB.

Item	DBH (Cm)	H(m)	AGB(Kg)
Mean	35.81	9.04	256
Minimum	5.41	2.1	163.23
Maximum	52.54	13.5	296.29
Pearson correlation (R^2)	0.98***	0.21ns	AGB

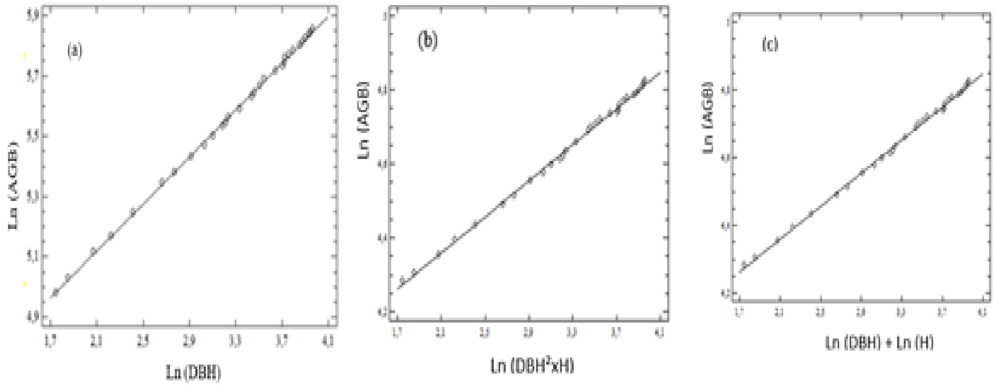
Note: DBH: Diameter Breast Height; H: Height; AGB: Aboveground Biomass; ***: Highly significant, ns: no significant.

Developed allometric equations: The models tested show very good performance. Taking into account the selection criteria, the best model is the one that takes into account the DBH (Table 2). Figure 2 shows the regression of the three models tested.

Table 2. Allometric models predicting AGB of cashew.

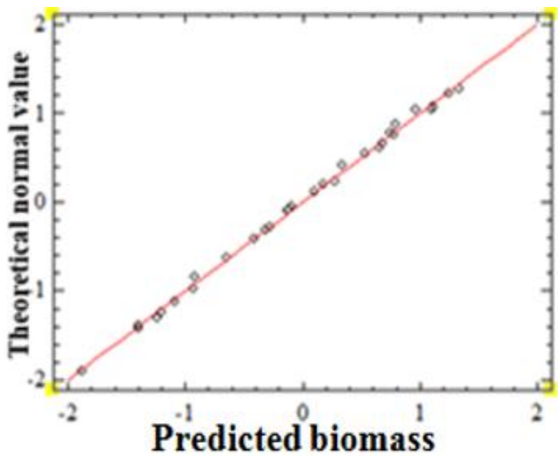
Equations	Coefficient			Performance criteria		
	a	b	c	adj R^2	AIC	p
Equation 1:In (AGB)=a+b × In (DBH)	4.66 (0.03)	0.28 (0.01)		0.98	-143	<0.00
Equation 2: In(AGB)=a+b × In (DBH^2 × H)	4.51(0.03)	0.01 (0.02)		0.97	-139	<0.00
Equation 3: In (AGB)=a+b × In (DBH)+c × In (H)	4.82 (0.02)	0.09 (0.00)	0.30 (0.03)	0.97	-131	<0.00

Figure 2. Linear regressions between (a) AGB with DBH; (b) DBH^2 × H; (c) DBH+H.



Residue normality and homogeneity: For all the selected models, the arrangement of the residues line instead of right of Henry justifies the adequacy of the models which show that the residues are distributed in a way likely to be adjusted by a Normal law. Shapiro Wilk's test does not reject the normality assumption for above-ground biomass (p-value=0.7402>0.05) (Figure 3).

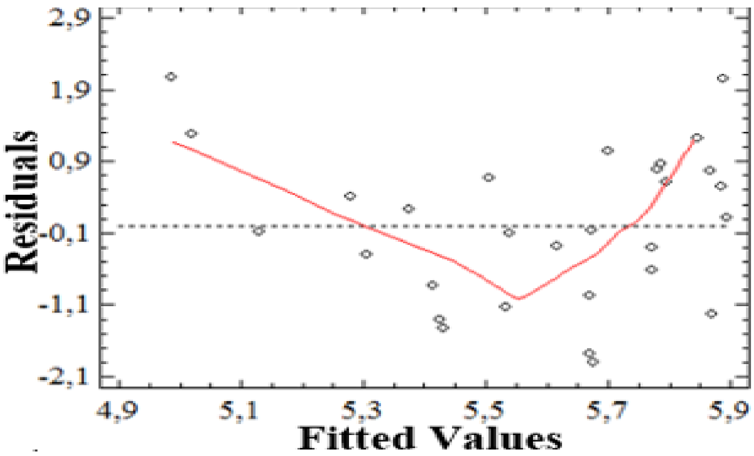
Figure 3. Normal distribution of residuals for aboveground biomass.



The cloud of residuals of the selected models is more or less homogeneous. The coefficients reflect the power of the effect of DBH on the aboveground biomass. The hypothesis of homogeneity of residuals is not rejected by the

Bartlett test, this is confirmed by the values of the p-value of each model chosen. Therefore have for above-ground biomass (p-value=0.7185>0.05) (Figure 4).

Figure 4. Plot of the residues according to the predicted values for aboveground biomass.



DISCUSSION

To develop the allometric equation for the prediction of cashew aboveground biomass, we felled 30 feet of cashew in the diameter interval 5.41 and 52.54 cm and in the height interval 2.10 and 13.50 m. This number of feet felled is comparable to those of (42 trees), (20 trees), (26 trees), (20 trees), (38 trees) and (40 trees) [15,18,24-27]. The sample size for the development of allometric models varies according to the availability of the species, the sampling device, the geographical environment and the resources allocated [8].

Three aboveground biomass prediction equations were tested in this study. Our study showed that using DBH alone as a predictor was the best fit for aboveground biomass (adj. R^2=0.98 and AIC=.-143). This result is similar to several studies in savannas, tropical and subtropical forests [25,28-31].

This while adding height as an additional predictor (DBH2 XH) did not improve equation 2 for aboveground biomass (adj. R^2=0.97 and AIC=.-139) in this study. This result is consistent with many previous studies such as those of [32,33]. Similarly, the addition of DBH with H (DBH+H) did not improve equation 3 for aboveground biomass (adj. R^2=0.97 and AIC=.-131) in this study. This result is consistent with many previous studies [17,18]. The methodology for the development of our models was based on checking the normality and homogeneity of the residual variances. These showed that Equation 1 only considering DBH as the predictor of aboveground biomass is the most important. This methodology for verifying the normality and homogeneity of the residual variances is consistent with those of [34-36].

CONCLUSION

It was a question for us in this study to develop an equation for predicting the aboveground biomass of cashew in Cameroon. Despite the destructive method, we felled 30 feet of cashew to establish our equations. Three aboveground biomass prediction equations were tested with two dendrometric variables (DBH and H). According to the two performance criteria (adj. R^2 and AIC), we found that the best equation for the prediction of aboveground biomass is the one that takes into account the DBH alone. The fit of the allometric biomass models AGB is Ln (AGB) = 4.66+0.28 × Ln (DBH). The specific allometeric equation developed for cashew which can be used in similar ecosystem in Cameroon for the implementation of Reduced Emission from Deforestation and Degradation (REDD+)

activities to benefit the local communities from carbon trade.

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