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Quantification of arboreal Species Biomass and Modeling the Volume of *Vernonanthura phosphorica* (Vell.) H. in the Arboretum of the Mandonge Forest Station

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Abstract

The aim of this work was to quantify the biomass of arboreal species and model the volume of *Vernonanthura phosphorica* (Vell.) H. in the Arboretum of the Mandonge Forest Station – Manica province. In the study, 4 transects were established and each transect had 3 square plots. The establishment of the plots allowed the identification of individuals, measurement of the diameter of breast height (DBH), total height of tree species and cut of some individuals per species. In the cut of individuals, the components of biomass were separated into stem, branches, leaves and weighed by compartment. For the modeling of the volume of *Vernonanthura phosphorica* (Vell.) H, the models of Husch, Schumacher-Hall, Meyer and Stoate were considered. According to the results, the total biomass of tree species was estimated in 23.42 Kg. Among the fifteen species studied, Vernonanthura phosphorica had the highest average of total biomass 3.67 Kg. The best model for estimating the volume of *Vernonanthura phosphorica* (Vell.) H was the Schumacher-Hall model, as it presents good statistics in relation to the other models.

Keywords: Measurement of tree components, phytomass and volumetric potential.

Introduction

In recent decades, there has been a growing interest in knowing the aspects that involve the dynamics of tropical forests, their development, their importance and forms of sustainable exploitation (Vismara, 2009). Recognition of the importance of forest ecosystem dynamics has grown a lot in recent years, given their potential to provide goods and services to human populations (Walker et al., 2011).

In Mozambique, forests are considered as wealth for the entire Mozambican population, as they are an important contribution to the economy, employment generation and rural livelihoods (Magalhães, 2018). Also according to the author, from the inventory carried out in 2017, it is estimated around 97.77Mg/ha of total biomass for each area unit.

According to Virgens et al., (2016) there is growing interest in diagnosing the biomass stock and volume of forests in order to create guidelines for future decision-making. The quantification of biomass informs about the potential of wood production for energy purposes or even contributes to understanding the changes that occur in the ecosystem.

However, studies with forest biomass also have other important purposes, highlighting quantification for energy purposes, carbon credit market, nutrient cycling and as an information base for forest management (Páscoa et al., 2008).

Furthermore, Rezend et al. (2006) point out that obtaining accurate estimates of biomass productivity in tropical plant formations is an important prerequisite for establishing management actions.

Another method of estimating forest potential refers to volume modeling (Thaines et al., 2010). According to Pereira et al. (2005) the techniques used in volume modeling aim to efficiently describe the behavior of tree trunks, using regression norms for modeling through statistical adjustment techniques that validate the tested models.

Cysneiros (2016) states that modeling is an excellent predictor after using regression to justify the correlation of the variables involved in the model, as well as applying statistics to verify the adherence of data to the model, eliminating possible biases related to estimation error. Given the above, the present work aimed to quantify the biomass of arboreal species and model the volume of Vernonanthura phosphorica (Vell.) H. This study is important for helping to understand the structural changes of the produced green mass and to understand how vegetation is recovered after natural or anthropogenic disturbance, providing important information for sustainable forest management in the Mandonge Forest Arboretum. In addition, the use of modeling to estimate the volume will minimize the costs incurred in forest surveys, as well as help to accurately determine the portion of volume existing in the arboretum of the species *Vernonanthura phosphorica* (Vell) H.

Methodology/approach

Study area

The work was carried out in the trial established in the 60s in the arboretum of the Forest Station of Mandonge, a Forestry Research Institution subordinated to Centro Zonal Centro, regional body of the Agricultural Research Institute of Mozambique (IIAM), located in the District of Sussundenga, in the Center of the Province of Manica.

Field data collection

In the study, 4 transects were established. In each transect there were 3 square plots with a dimension of 30x30m whose objective was to collect individuals with established regeneration and adults. Within the plot, a 5x5m subplot was established where individuals of non-established regeneration were measured. Within the plot, was determined, the diameter of the breast height (DBH) was measured, the total height of the tree species and the slaughter of some individuals per species. Still in the field, the arboreal individuals had their species recognized by the common name, and a sample was taken for botanical identification.

Quantification of biomass and volume

The sampling of trees for the quantification of biomass was carried out by the direct method. Each sample tree was measured to obtain DBH, total height and volume, using rigorous cubing using the Smalian method. After cubing, each sample tree was divided into leaves, branches (branches with diameter < 5 cm) and shaft, which were weighed on a mechanical scale, with a capacity of 150 kg and precision of 50 g, to determine the green biomass. Sub-samples were separated from each compartment, which were taken to the laboratory and had their wet and dry masses (after drying in an oven) determined with the aid of a precision balance (0.01 g). The dry biomass of each of the tree components was estimated based on the relationship between dry mass and wet mass of the sample. The dry biomass values of the sample trees together were projected for ha, considering the average biomass by DAP class.

Modeling the volume

For the volumetric modeling, four volumetric models were considered, of which 2 non linear and 2 linear (Table 1).

Table 1: Volumetric models tested to estimate the volume of *Vernonanthura phosphorica* (Vell.) H.

Models	Author
$V_i = \beta_0 DAP^{\beta_1} + \varepsilon_i$	Husch
$V_i = \beta_0 DAP^{\beta_1} H^{\beta_2} + \varepsilon_i$	Schumacher e Hall
$V_i = \beta_0 + \beta_1 DAP + \beta_2 DAP^2 + \beta_3 DAPH + \beta_4 DAP^2 H + \beta_5 H + \varepsilon_i$	Meyer
$V_i = \beta_0 + \beta_1 DAP^2 + \beta_2 H + \beta_3 DAP^2 H + \varepsilon_i$	Stoate

Where: V_i= volume per tree; DAP = diameter at breast height; H_i = tree height; β_i = model parameter; ε_i = random error, being $\varepsilon \sim N(0, \sigma^2)$.

Among the commonly used statistical criteria, the evaluation of the quality of volumetric model adjustments was performed based on the Schlaegel adjusted adjustment index and mean square error. The models Meyer and Stoate for possessing many independent variables, it was modified by applying *Stepwise* to select which variables most influence the output set, thus reducing the number of variables to compose the final regression equation.

Results

The Table 2 shows the biomass of tree species in the different compartments (leaf, branch and stem), referring to the studied species. According to Table 2, the total biomass of tree species was estimated at 23.42 Kg tree^{-1}, of which it ranged from 0.34 to 3.67 Kg tree^{-1}. Among the fifteen species studied, *Vernonanthura phosphorica* had the highest total biomass average of 3.67 Kg tree^{-1}, followed by *Gmelina arbórea* 3.55 Kg tree^{-1}, *Parinari curatelifolia* 3.04 Kg tree^{-1}, *Erythroxylum emarginatu* 2.26 Kg tree^{-1}. The species that presented the lowest biomass average was the species not identified by its scientific name designated as unidentified 1, with an average of 0.34 Kg tree^{-1}.

Regarding the contributions of different compartments of tree biomass, they were distributed as follows: stems> branches> leaves.

Table 2: Average total biomass of tree species in different compartments.

		Biomass							
		Leaf		**Branch**		**Stem**		**Total**	
Family	**Species**	Kg tree^{1}	%	Kg tree^{-1}	%	Kg tree^{-1}	%	kg tree^{-1}	%
Asteraceae	*Vernonanthura phosphorica*	0.46	15.91	0.72	16.95	2.49	15.30	3.67	15.67
Myrtaceae	*Psidium guajava* L	0.14	4.69	0.38	9.06	0.59	3.59	1.10	4.72
Asterácea	*Brachylaena discolor*_DC	0.22	7.68	0.67	15.91	1.02	6.28	1.92	8.20
	unidentified 1	0.16	5.40	0.00	0.00	0.18	1.12	0.34	1.45
Erythroxylaceae	*Erythroxylum emarginatu*	0.23	7.79	0.46	10.82	1.57	9.66	2.26	9.64
Bignoniaceae	*Stereospermum kunthianum*	0.11	3.88	0.12	2.91	1.27	7.82	1.51	6.45
Apocynaceae	*Tabernaemontana elegans*	0.15	5.32	0.17	4.12	0.91	5.59	1.24	5.29
Chrysobalanaceae	*Parinari curatelifolia*	0.15	5.32	0.38	8.87	2.52	15.44	3.04	13.00
	unidentified 2	0.21	7.34	0.50	11.74	1.34	8.22	2.05	8.75
	Brachiaria chusqueides	0.13	4.63	0.00	0.00	0.22	1.33	0.35	1.50
Leguminosae	*Parkia filicoidea*	0.18	6.28	0.00	0.00	0.22	1.36	0.40	1.72
Lamiaceae	*Gmelina arbórea*	0.21	7.26	0.37	8.84	2.97	18.22	3.55	15.17
Lamiaceae	*Vitex payos*	0.18	6.16	0.18	4.28	0.12	0.73	0.48	2.04
Cannabaceae	*Trema orientalis* (L)	0.16	5.36	0.05	1.21	0.18	1.13	0.39	1.67
Rubiaceae	*Craterispermum triflora*	0.20	6.98	0.22	5.28	0.68	4.20	1.11	4.74
	Total	2.90	100.0	4.23	100.0	16.29	100.00	23.42	100

Source: The autor

The equations obtained with their respective statistics are presented in Table 3. The results indicate a good performance for all models in terms of Schlaegel's adjusted fit index and square root of the mean error, which statistically shows that all methods can be used for the estimation of the volume of *Vernonanthura phosphorica*. The Schumacher and Hall model had the highest performance compared to the other models, with Schlaegel's adjusted fit index (%) = 98.05 and square root of the mean error (%) = 1.57.

Table 3: Equations and statistics used to select the best model.

Models	**Equation**	IA_{aj} **(%)**	RMSE (%)
Husch	$\hat{V}_i = 0,00135 * DAP^{2,530177}$	96,66	3,05
Schumacher e Hall	$\hat{V}_i = 0,000045 * DAP^{1,8378} * H^{1,0634}$	98,05	1,57
Meyer	$\hat{V}_i = -0,500577 + 1,7528 * DAP^2H + 1,4596 * DAP$	97,10	2,07
Stoate	$V_i = -9,331 - 609,255DAP^2H$	97,09	2,49

Source: The autor

Discussion

Due to the fact that the species *Vernonanthura phosphorica* presents the highest average of the total biomass of the species studied, it can be said that the species in question is quite important in the forest with regard to ecological functions, due to its high rate of biomass production, as well as, production of nutrients, by its deposition of green and dry mass in the soil.

The low participation of leaves observed for all species studied can be attributed to the deciduous behavior of trees, which is common in most tree species, losing their leaves in the dry period, as a natural mechanism for prevent water loss through transpiration.

On the other hand, the greater participation of the shaftis due to the fact of greater carbon storage as this represents the largest reservoir in the plant when compared to other components in the compartments.

The Schumacher-Hall model is often used in the development of stem volume equations. The superiority of the Schumacher-Hall model was clearly demonstrated in this study. This model is difficult to be surpassed, because the logarithmic conformation and the combination of the independent variables diameter breast height and height give it very favorable statistical properties in the volumetric estimation.

However, several studies carried out for volume modeling have reported the robustness of this model to estimate volume (Bi, 1994; Tewari and Kumar, 2003; Azevedo et al., 2011).

Conclusions/ wider implications of findings

Among the fourteen species with the highest population density under the conditions of the Arboretum of the Mandonge Forest Station, the species *Vernonanthura phosphorica* (Vell.) had the highest biomass stock. The contributions of the different compartments of tree biomass were distributed as follows: stems> branches> leaves.

The Schumacher-Hall model showed a better static fit compared to the other models in estimating the individual volume of *Vernonanthura phosphorica* (Vell.).

The study on forest biomass quantification and volume modeling in the Arboretum of the Mandonge Forest Station is of great importance given the scarcity of information, which somehow makes us understand that the volumetric and biomass parameter is little studied or little published.

The volumetric estimates is a quantitative variable that, when determined in a adequate, allows the management and planning of forest resources. Therefore, volumetric estimates will provide knowledge of the forest potential, forest productivity and a basis for planning forest management in the Arboretum of the Mandonge Forest Station

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