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Local Allometric Equations for Estimating Above-Ground Biomass (AGB) of Mangroves *(Rhizophora spp*. and *Avicennia germinans*) from the Komo, Mondah and Rio Mouni Estuaries in Gabon

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Abstract

The aboveground biomass (AGB) of Gabonese mangroves is commonly estimated from equations calibrated in other countries, and is generally adapted poorly to the local context. This paper focuses on developing local allometric equations for the AGB estimation and to evaluate their accuracy compared to other general equations. The local equations for Rhizophora spp and Avicennia germinans were performed with tree volume, bark and wood densities, and are used with the diameter as an independent variable. The heights and diameters of 408 trees (314 Rhizophora spp and 94 Avicennia germinans) were measured at 13 sites in Estuaire Province. Sixty-four aliquots were taken from the trunks of both species at the Mondah site. This site has tree diameters ranging from 2 to 127 cm for Avicennia and from 1.4 to 75.8 cm for Rhizophora. The tree height ranges from 0.9 to 24 m for Avicennia, and from 1.1 to 53 m for Rhizophora. Avicennia has an overall trunk density of 0.88 g/cm3 and Rhizophora has 1.17 g/cm3. The coefficient of determination (R2) of the equations are 0.98 for Rhizophora spp, 0.97 for Avicennia germinans, and 0.99 for the general equation. The seven equation display biases that are less than 1% and the root mean square errors vary between 0.073 and 1.68. Compared to other equations generally used, these local equations improve the accuracy of aboveground biomass estimations of Gabonese mangroves.

Mots clés: Mangrove Biomass, Allometric Equation, Density, Avicennia, Rhizophora, Gabon

Introduction

Mangrove forests, also known as tropical maritime marshes (Lebigre, 1990), are one of the main terrestrial biomes found on the coasts of the intertropical zones between the 32° North and 38° South parallels (Bunting et *al*., 2021). It is located in the transition or tidal swing zone between oceanic salt water and continental fresh water. This ecosystem is made up of trees, shrubs, and sea grasses adapted to a wide range of salinity leading to a zonation of species parallel to the coastline. They develop in sheltered environments, and are therefore protected from marine currents in river mouths (coastal rivers, lagoons, estuaries and deltas). Mangroves are present in 120 countries (except in Europe), covering an area of about 150 000 km^2, and they are grouped in two major biogeographic areas (Indo-Pacific and Atlantic). Composed of several halophyte species, this environment plays an important socio-ecosystemic roles, providing benefits to populations in terms of food security, as up to 75% of commercial tropical fish species spend part of their lives in mangroves (Kauffman & Donato, 2012). Mangroves also provide other important services as they protect the coast from erosion, and also contribute to the transformation of atmospheric CO_2 into organic matter via photosynthesis. Production is estimated at about 50 tons of CO_2 equivalent/ha/year (Marchand, 2015). Climate change research determines that these ecosystems provide the largest carbon stocks in the world (Kauffman & Donato, 2012).

The Gabonese coast, which is about 950 km long, harbors 2500 km^2 of mangroves (Lebigre, 1990). A recent study, conducted by NASA researchers on the northern coast, underlined the exceptional character of Gabonese mangroves (Simard et *al*., 2019b). It revealed the existence of the highest mangroves, with tree heights exceeding 60 m. Diameters at breast height (DBH) have been measured at up to 127 cm in Mondah's estuary (for this study). This is an important structural difference between local mangroves and those in other regions of the world (Kauffman & Bohmia, 2017). The genus *Rhizophora* is dominant with three species namely; *Rhizophora mangle, Rhizophora harrisonii, and Rhizophora racemosa* (Ondo Assoumou, 2006; Ajonina et *al*., 2014b). It is followed by three other pure mangrove species including *Avicennia germinans* (Avicenniaceae), *Laguncularia racemosa*, and *Conocarpus erectus* (Combretaceae); two companion species including *Phoenix reclinata* (Palmaceae), *Acrostichum aureaum* (Pteridaceae); and an occasional *Paspalum vaginatum* (Poaceae) (Ondo Assoumou, 2017).

However, these same mangroves, at global and local scales, are among the most threatened ecosystems due to population growth in the coastal zone and its overexploitation. For instance, the loss of mangrove in the world was estimated at 20% between 1980 and 2005 (FAO, 2007). One of the causes mentioned is urbanization (Cormier-Salem, 1999; IUCN, 2006; FAO, 2007). In Gabon, mangrove losses from the same causes are estimated at 685 km^2 between 1980 and 2005, and 54 km^2 between 2000 and 2010 (Howard, 2014; Ajonina et *al.*, 2016). The consequences associated with climate change, accompanied by temperature increases, sea level rise and increased CO_2 concentrations, are very worrying for the populations, their health, their economies, and the biodiversity of the world.

Therefore, several tools such as allometric equations are dedicated to biomass and carbon estimation (FAO, 1993, 1994; Fromard et *al*., 1998; Komiyama et *al*., 2005; Chave et *al*., 2005; Ajonina, 2008; Kauffman & Donato, 2012). Yet, estimations using general equations calibrated in other parts of the world could present variations of locally estimated biomass, and may not be appropriate (Soares & Schaeffer-Novelli, 2005; Kirui et *al*., 2006).

In the absence of a local allometric equation, commonly used equations for tree biomass estimation are, among others, those gotten from Fromard et *al*. (1998), Komiyama et *al.* (2005), Chave et *al.* (2005), and Kauffman et *al.* (2012). However, none of these equations have been calibrated with mangrove data from Gabon or even Central Africa, but rather from America, South East Asia or Australia (Kauffman et *al*., 2012). Hutchison et *al.* (2013) proposed a global mangrove biomass map elaborated with models that were set up for the purpose. However, model development

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did not include data from Central and West African mangroves. As a result, mangroves from these regions are presented with low AGB and BGB values. On the contrary, the study by Spalding et *al.* (2010) identified Central and West Africa among the regions with the highest AGB and BGB. Is this contradiction not related to the absence of data from these regions in the model calibration?

In Central Africa, Ajonina et *al.* (2014b) implemented a general biomass prediction model with a DBH range of 1 to 102.8 cm. However, no equations are specific to neither mangrove species nor tree components (bark, wood) in Gabon. Thus, the need to set up local models is obvious (GIEC, 2001).

The aim of this paper is to develop local aboveground biomass estimation equations using easy-to-measure dendrometric parameters, and to discuss their accuracy by comparing to other general equations. These local equations are formulated for bark, wood, and mix (wood + bark) densities of *Avicennia germinans* and *Rhizophora spp*.

1. Materials and Methods

1.1. Study Sites

Across longitudes 9°15' and 10°50' East and latitudes 1°30' South and 1°10' North, the Estuaire province covers 20,740 km^2. The climate is marked by four seasons: two dry seasons and two rainy seasons. The duration of the dry season is short (three months for both periods). July is the driest month, while March, April and November are the wettest months, with total monthly precipitations of 313.5 mm in April and 445.8 mm in November. The average annual minimum and maximum temperatures are 23°C and 29°C, with an average of 27°C in Libreville (Maloba Makanga, 2011).

The province has three mangrove areas, namely the Komo, Mondah and Rio Mouni estuaries, located in northwestern Gabon (Map 1 below). They represent 40% of the country's mangroves (Lebigre, 1990). With 1051 km^2 of surface in 2017 (Okanga-Guay et *al*., 2019), they are mainly composed of *Rhizophora spp* (Rhizophoraceae) and *Avicennia germinans* (Avicenniaceae) species.

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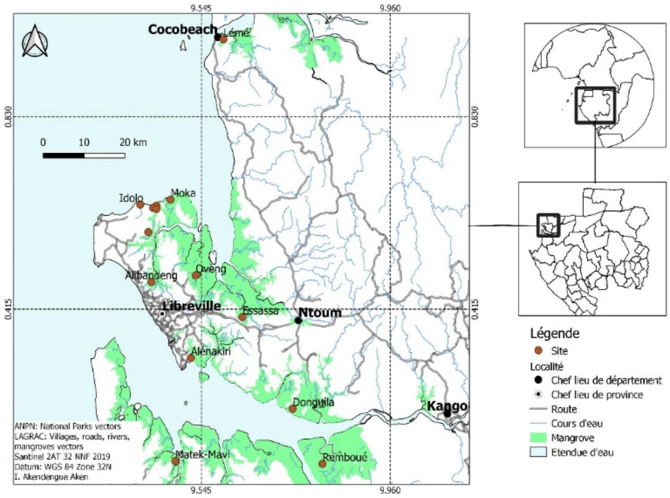

Map 1. Location of Mangroves in Gabon's Estuary Province (Sentinel 2A imagery, 2019; LAGRAC vectors, 2020)

A total of 13 sites were sampled: 5 sites in the Komo estuary, 7 sites in the Mondah estuary, and 1 site in the Rio Mouni estuary.

1.2. Field Data Collection Methods

1.2.1. Experimental Design

To develop local allometric equations for mangrove trees, three preliminary steps are conducted: 1- sampling of sites, trees and aliquots, 2- aliquots preparation, and 3- aliquots and data treatment (Figure 1). Variables needed are bark and wood densities, tree heights, and diameters.

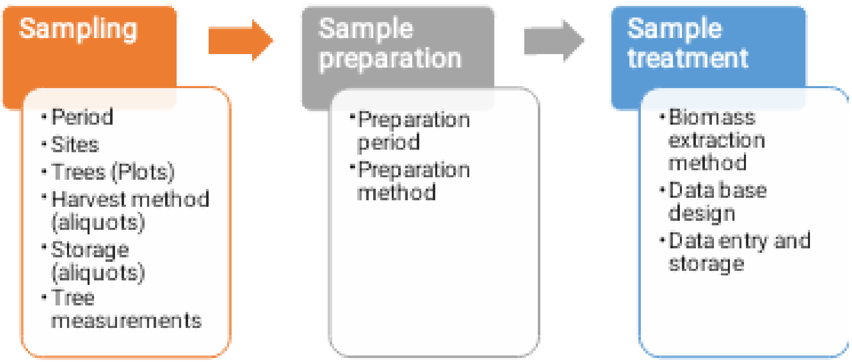

Figure 1. Workflow of Field AGB Data Collection and Treatment

1.2.2. Sampling

The choice of sites was determined by directed sampling using remote sensing to locate mangroves around Libreville that are accessible by boat, road or hiking. Data collection was done in 2018 and 2019 for 408 mangrove trees of *Avicennia germinans* (94 individuals) and *Rhizophora spp* (314 individuals). Minimally and non-invasive methods were used for sampling, as some sites are located in protected areas.

Data for model development was collected from 64 individuals at one sample site of the Mondah Estuary. Among those trees, 64 trunk aliquots (bark and wood) of a few square centimeters were collected with a saw on *Avicennia* and *Rhizophora* individuals inside 4 squares plots of 10m x 10m (0.01ha). The samples were taken at breast height for *Avicennia* and at 50 cm over the last root for *Rhizophora*. The harvested samples were put in identified individual plastic bags.

Data for model validation was collected in the 3 estuaries: 5 sites in the Komo, 7 sites in the Mondah, and 1 site in the Rio Mouni. A total of 344 individuals (of *Avicennia* and *Rhizophora* genera) were used for validation: 92 for 1st validation and 252 for 2nd validation.

1.2.3. Tree Measurements

Dendrometric parameters were recorded for 408 mangroves trees in 16 plots (1 plot per site except for the aliquots sample site where there are 4 plots). The heights were measured by a laser range finder (Nikon Forestry Pro Model). The forest measuring tape was used to determine the diameter at breast height (DBH) for *Avicennia germinans*, and the diameter at 50 cm above the last root for *Rhizophora spp*.

1.3. Laboratory Methods

Designing allometric equations for bark, wood, and mix (bark + wood) of *Rhizophora spp* and *Avicennia germinans,* mangrove species was divided in 3 major steps: estimating field AGB, building allometric equations using DBH and validation.

1.3.1. Estimating Field Aboveground Biomass

In the laboratory, samples of harvested wood and bark were cut into cubes to measure their width, length, and thickness. A first weighing was done to have the wet mass. The samples were put in the oven at a constant temperature of 70°C for 48 hours. Then, they were re-weighed to determine the dry mass. The volume and density of each sample was determined by equation 1 and 2 as follows:

Volume of sample (v) = h * L * l (Picard and *al*., 2012) (Equation 1)
where h = thickness, L = length and l = width.

Density of sample (P) = M / v (Picard and *al*., 2012) (Equation 2)
where M is the dry mass of each sample.

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Estimations of aboveground biomass were obtained according to the standard method of Husch et *al*. (2003) which was implemented in mangroves by Ajonina (2008) (Equation 3, 4 and 5):

Basal area (g) = $\pi * d^2 / 4$. (Equation 3)

Volume of tree (V) = f * g * H. (Hush and *al*., 2003) (Equation 4)

Aboveground biomass (AGB) = P * V * BEF (Equation 5)

Where d = diameter, H = height of tree, f = mangrove form factor which equals 0.6 (Ajonina & Usongo, 2001), P = density, and BEF = mangrove biomass expansion factor which is determined at 1.18 (Ajonina, 2008).

The calculations were made in MS Excel and were automatically integrated in a general data base. These first results consisted of estimated AGB per wood component of individuals and per species.

1.3.2 Building Allometric Equation using the Diameter Parameter

Estimated AGB, as well as corresponding diameters, were used as entry data to build allometric equations for each component and species.

The models were adjusted with R.3.3.4 software in order to find suitable coefficients, with the sum of squares of the differences between the estimated field values and the theoretical values retaining the most insignificant possible. Single-input models using DBH were preferred, being the easiest parameter to measure in a somewhat giant mangrove, as it is the case in some of the sites. The use of diameter, without height, is usually sufficient to accurately estimate AGB (Putz & Chan, 1986; Clough & Scott, 1989; Comley & McGuiness, 2005; Kirui et *al*., 2006; Sitoe et *al*., 2014).

The model’s form is defined by the relationship between the AGB estimates and the DBH measured in the field using R.3.3.4 software.

1.3.3 Allometric Equation Validation

Two steps of model validations were done. The first validation of the models used supplementary data of the same site as the data used for model development. The coefficient of determination (R^2) and the Akaike information criterion (AIC) were used to select the appropriate models. The second validation used the data of all the other 12 sites. The equations were evaluated by comparing predicted biomass and estimated field biomass (Chave et *al*., 2005) (Equation 6, 7 and 8):

$$RMSE = \frac{1}{N}\sum_{1}^{n}\left(\left((P_i - O_i)^2\right)/ N\right) * 0.5 \qquad \text{(Equation 6)}$$

$$BIAS = \frac{1}{N}\Sigma_i^n (P_i\text{-}O_i) \qquad \text{(Equation 7)}$$

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$$\text{BIAS}(\%) = \frac{1}{N}\sum_i^n \frac{(P_i - O_i)}{|O_i|} \qquad \text{(Equation 8)}$$

Where RMSE = square root of the mean squared error,
P = predicted biomass and O = observed or estimated field biomass.

RMSE was used to measure accuracy, i.e., as a standard statistical metric to measure model performance or model errors (Chai & Draxler, 2014). Bias is the difference between the predicted value and the true value (in this case the AGB estimation). The best model is always the one with the smallest AIC and bias values, which is the highest coefficient of determination (r^2) and the smallest RMSE.

After estimating the adjusted parameters of the models, seven equations were obtained. Three types of biomass prediction equations (AGB) were developed for each species: AGBbark (bark), AGBwood (wood), and AGBmix (mix). A general model, combining both species, was also proposed. The resulting equations were in the power form $y = \alpha x^{\beta}$, corroborating with AGB equations of other mangrove species according to Kirui et *al*. (2006) and Scales and Friess (2019).

Specific allometric equations for each species were compared with a produced general equation (for all components of both species) and other equations from the literature.

2. Results

2.1. Bark, Wood and Mixed Masses and Densities

The dry mass of the trunk varies from 0.03 to 2.12 g, with 7.98 g of a typical value. There is also a variability of dry mass in the bark and wood. Thus, the minimum and maximum mass of the bark were respectively 0.19 g and 1.55 g, and of the wood 0.03 g and 2.67 g.

Avicennia germinans has a density of 0.76 ± 0.19 g / cm^3 for bark, 0.99 ± 0.38 g / cm^3 for wood and 0.88 ± 0.21 g / cm^3 mixed density (Table 1). *Rhizophora spp* has 1.58 ± 0.72 g / cm^3 for bark density, 0.77 ± 0.12 g / cm^3 for wood and 1.17 ± 0.36 g / cm^3 of mixed density (Table 1). According to the Fisher test, the critical probability (p-value) is 0.016, which is well below 0.05. The variance in density is therefore significantly different between *Avicennia germinans* and *Rhizophora spp*. The confidence interval, at an alpha threshold of 95%, is 0.20, 0.84, and the quotient of the variances is 0.41. The Student's test has a critical probability (p-value) of 0.48, which is greater than 0.05. The density averages between *Avicennia germinans* (0.88 g / cm^3) and *Rhizophora spp* (1.18 g / cm^3) are therefore 95% identical in the confidence interval [-1.16; 0.6].

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Table 1. Statistical Characteristics of the Measured Dendrometric Parameters used for Model Development and 1st Validation

Statistics	*Avicennia germinans*					*Rhizophora spp*					*Mix species*				
	DBH (cm)	Height (m)	Bark density (g/cm^3)	Wood density (g/cm^3)	Mix density (g/cm3)	DBH (cm)	Height (m)	Bark density (g/cm^3)	Wood density (g/cm^3)	Mix density (g/cm^3)	DBH (cm)	Height (m)	Bark density (g/cm^3)	Wood density (g/cm^3)	Mix density (g/cm^3)
N	58	58	18	18	36	98	98	14	14	28	156	156	32	32	64
Min	2	0.9	0.06	0.04	0.04	1.4	1.1	0.08	0.08	0.07	1.4	0.9	0.06	0.04	0.04
Max	127	24	3.53	7.23	7.23	75.8	53	1.76	10.3	10.3	127	53	10.03	7.23	10.03
Mean	29.79	11.33	0.759	0.994	0.876	12.92	9.22	0.78	1.58	1.17	19.19	10	1.12	0.9	1
Stand. Dev.	25.07	5.75	0.79	0.38	0.95	17.03	8.62	0.45	2.71	1.95	22	7.73	1.7	1.23	1.59
Stand. Error	3.29	0.75	0.19	1.61	1.25	1.72	0.87	0.12	0.72	0.36	1.8	0.62	0.33	0.21	0.2

2.3. Diameter (DBH) Structure of Sampled Mangroves

The prediction domain of *Rhizophora spp* models is between $1 \leq$ DBH <80 cm, which is based on Ajonina's (2008) nomenclature between seedlings and matures. The most dominant categories are seedlings and poles, followed by posts for *Rhizophora* (Figure 2). For *Avicennia germinans*, the prediction domain is rather between $2 \leq$ DBH <100 cm, as diameter over 100 cm are exceptional. Field data has determined that the dominant categories for *Avicennia* are poles, posts, and standard. The number of individuals usually becomes scarce as one progresses towards the large DBH classes.

According to this sampling, less than 20 individuals of *Rhizophora spp* have 30 cm DBH or more. On the other hand, less than 10 individuals in *Avicennia germinans* are observed in seedling or mature classes. In this sample, the probability of encountering large individuals is higher in *Avicennia germinans*. The ecological and structural conditions of the *Rhizophora* species explain the rarity of large individuals. The configuration of its stilt roots allows it to fix well and fight against submersion. However, its roots are in danger when the tree takes volume. Large DBHs are rare and are outlined by the maximum values of the *Rhizophora* allometric equations of Komiyama et *al*. (1988), Fromard et *al*. (1998), or Ong et *al*. (2004) who recorded maximum DBH of 47.1cm, 32cm, and 28cm respectively.

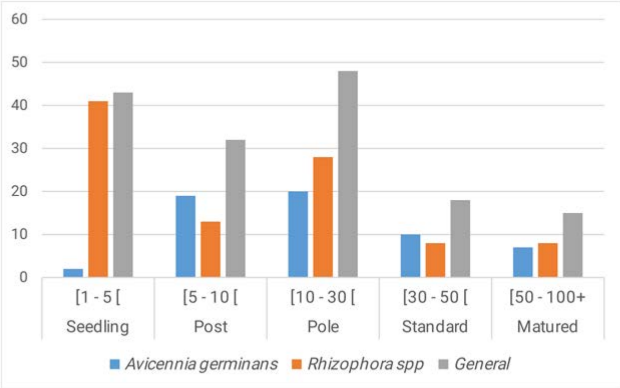

Figure 2. Diameter Distribution for Model Development and 1st Validation

2.4. Aboveground Biomass Model Validation and Prediction Results

Except for the general model, the three types, AGBbark, AGBwood, and AGBmix, are specific for *Rhizophora spp* or *Avicennia germinans*, with a determination coefficient of 0.98 and 0.97 each (Table 2).

Rhizophora spp biomass prediction models have an Akaike information criterion (AIC) of 91 for the bark, wood, and mix types. *Avicennia germinans*' three prediction models of aerial biomass (bark, wood and mix) have an AIC of 35. Among the seven allometric equations, AGBmix for *Rhizophora spp* would be more accurate according to RMSE, as AGBwood for *Avicennia germinans* would present the least bias.

The AGBbark of *Rhizophora spp* model has an RMSE of 0.123 with an average error of 0.041 or 0.464% bias. The RMSE of the AGBwood *Rhizophora spp* model oscillates around 0.129, and have an average error of 0.043 or 0.999% bias. The AGBmix *Rhizophora spp* model has an RSME of 0.073 and an average error of 0.024 or 0.375% bias.

The root mean squared error (RMSE) of the AGBbark model for *Avicennia germinans* is 0.139 with an average error of 0.048 or -0.221% bias. The AGBwood *Avicennia* model has an RMSE of 0.157 and -0.046% bias. The RMSE of the AGBmix model of the same species is 0.172 with an average error of 0.063 and -0.158% bias. All three models have a mean standard error of less than the average of 0.02. The general model for both species has a bias of 0.32% and a RSME of 1.68.

Table 2. Statistical Characteristics of the Models used for Biomass Prediction of *Rhizophora spp* and *Avicennia germinans* in Gabonese Estuaire Province

Species	Pools	α	B	R^2	AIC	RMSE	Bias (%)	Allometric equations
Rhizophora spp	bark	7.10E-05	2.79	0.98	91	0.123	0.464	$AGB=0.00007104DBH^{2.79}$

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	wood	4.76E-05	2.79		91	0.129	0.999	$AGB=0.0000476DBH^{2.79}$
	mix	6.18E-05	2.79		91	0.073	0.375	$AGB=0.0000617 6DBH^{2.79}$
Avicennia germinans	bark	1.34E-04	2.37	0.97	35	0.139	-0.221	$AGB=0.0001343DBH^{2.37}$
	wood	1.76E-04	2.37		35	0.157	-0.046	$AGB=0.0001760DBH^{2.37}$
	Mix	1.55E-04	2.37		35	0.172	-0.158	$AGB=0.0001545DBH^{2.37}$
General model	Mix	3.82E-05	2.76	0.99	60	1.68	0.32	$AGB=0.0000381DBH^{2.76}$

For *Rhizophora spp*, AGB predictions of bark and wood differ, especially when it approaches a DBH that surpasses 30 cm (Figure 3A). Its bark carries more biomass than the wood. The general model underestimates biomass at values of DBH over 40 cm.

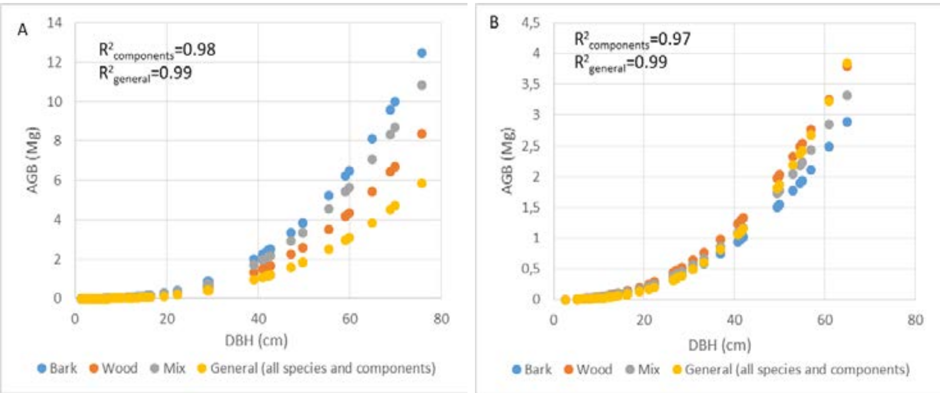

Figure 3. Predictions of AGB for *Rhizophora spp* (A) and *Avicennia germinans* (B)

For *Avicennia germinans*, AGB predictions of the three components (bark, wood and mix) are similar (Figure 3B). Wood AGB is only slightly higher than that of the bark. The general model overestimates AGB at very big DBH (100cm diameter or higher, not on figure).

3. Discussion

Predicting biomass with the use of allometric equations is a key element to estimate the contribution of diverse forest ecosystems to the carbon cycle (Picard et *al*., 2012, p 17). With very variable heights in Gabon (up to 62,8m calculated by Simard et *al*., 2019a), measuring only mangrove diameters would accelerate data collecting, especially with the very difficult conditions imposed by this particular ecosystem.

To ensure precision, wood densities (bark, wood and both) were included in the first step of estimating AGB. These estimations were then incorporated in the building process of the allometric equations. The results prove satisfactory and are generally similar to those used in West or Central Africa. When applied to our data, the adjusted volume model established by Ajonina et *al*. (2014a) in Benin, transformed in an AGB model, has a RMSE of 0.167, which is inferior to our general model with a RMSE of 1.68. Nonetheless, its bias is at -0.419% while ours is at 0.32%. All of our allometric equations for tree components (bark or wood) have lower RMSEs than Ajonina's general model for the mangroves of Benin. More geographically close, the model from Cameroon has a similar margin of error as the general mixed model (0.016 average errors and a 0.256% bias) (Ajonina et *al*., 2014b). This similarity is not the case for other models. The mixed models of Fromard et *al*. (1998) and Komiyama et *al*. (2005) for *Avicennia germinans* mangroves in French Guiana and Southeast Asia have an average margin of error of 84.96 for the first and 166.09 for the second. Even if the models developed are apply for the same species, the differences in margins are mainly due to site specifications, as South American or Asian mangroves differ from Gabonese mangroves. They may be related to environmental conditions, clinometric, and dendrometric aspects of the species. The biomass prediction model of Fromard et *al* (1998) has a margin of error between -11.7% and 3.99% for *Avicennia germinans*, which better reflects its relevance in French Guiana. The margins of error in the prediction models of *Avicennia germinans* vary from one author to another in the literature, but do not go beyond ± 30% (-30% for Comley & Mc Guinness, 2005; -4.05 and 10.8% for Imbert & Rollet, 1989; 13.4 and 3.26% for Clough et *al*., 1997).

The comparisons with other models of the literature, applied to DBH found in this study area, shows a variability of the margin of error. Margins of error increase with the remoteness of the original calibration location of the model. Thus, the use of the Komiyama et *al*. (2005) model gives an average error of 49.63, and a mean error of 50.54 as stated by Fromard et *al*. (1998). Those geographically distant AGB models (Fromard et *al*., 1998; Komiyama et *al*., 2005) have a large margin of error. When put in context, these models have error margins ranging from -9.84 to 10.3% for general models and between -8.44 and 6.79% for specific models. That is an average of 7% more than our general model which has a bias of 0.32%. The AGB models of *Rhizophora spp* have a small variation in margin of error, unlike *Avicennia germinans* models. The models developed have a bias between -0.158 and -0.365% for the species *Avicennia germinans*, thus they underestimate the AGB. This may be due to errors in the collection, entry, or not taking into account one or more other parameters.

This adds height or density, if not both, as independent variables in allometric equations could improve model accuracy (Picard et *al*., 2012). Furthermore, the volume estimation, according to the Husch et *al*. (2003)

method, requires the use of a biomass expansion factor (BEF). For this study, a factor of 1.18 from the literature was used (Ajonina, 2008). Like allometric equations, the BEF varies from region to region. Setting up a local BEF would provide additional precision in estimating volumes (Moundounga Mavouroulou, 2012).

Conclusion

From this study, seven local aboveground biomass models adapted to mangroves in the Estuaire Province of Gabon. The models developed are as follows: 3 models (bark, wood and mix) for *Avicennia germinans*, 3 models (bark, wood and mix) for *Rhizophora spp* and 1 general model (all components for *Avicennia* and *Rhizophora*). The results prove to be satisfactory as the predictive specific and general allometric equations show low RMSE and biases under 1%. Their accuracy is similar to the local models of Benin and Cameroon (Ajonina et *al*., 2014a; 2014b). This is not the case when comparing to allometric equations developed in other regions, such as French Guiana and Southeast Asia. Environmental, clinometric, and dendrometric conditions of the species in these locations certainly influence AGB and allometric relations. Locally built models can increase accuracy of aboveground biomass estimations of mangrove forests.

For the moment, the Estuaire Province aboveground biomass models safely predict AGB for diameters up to 100 cm for *Avicennia germinans*, and 80 cm for *Rhizophora spp*. Surveys in some parts of Gabon, carried out under the MDMLERD project, show that both species can grow beyond these values. The preliminary work presented here needs to be deepened with the integration of very large individuals, local biomass expansion factor (BEF) determination, and remotely sensed biomass assessment for the entire extent of Gabonese mangroves.

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