TEST DEVELOPMENT OF MULTI-SPECIES ALLOMETRIC EQUATIONS FOR THE QUANTIFICATION OF THE CARBON STOCK OF SOME SPECIES OF FOREST GUINEA.

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ABSTRACT

This study is based on the development of allometric models of the Trichilia Septentrionalis species of the classified forests of Ziama, Mont Nimba, Béro, Pic de Fonc and Diécké in Forest Guinea. Its purpose is to establish a basis for calculating carbon stocks from allometric models for estimating aboveground biomass. The tree sample consists of 375 feet of Trichilia Septentrionalis. The direct method of felling and weighing compartment by compartment of biomass is based on the use of tree samples. The criteria for selection and validity of the models are based first of all on the tests of normality, nullity, heterogeneity and autocorrelation of the residuals. Following the tests carried out, we analyzed the errors, in particular the standard residual error (CSR) and the Akaike information criterion (AIC). The results show that the power model is explicit with a residual error of 0.0443 or 4.43% and a lower AIC compared to equation (7) which has a high residual error at the same time as the AIC . Due to the fact that the standard residual errors (CSR) and the Akaike information criterion (AIC) of the other eight (8) equations are not suitable for the study of this forest species. This means that the power model is best suited to study the aboveground biomass of the species Trichilia Septentrionalis in Forest Guinea. The study confirmed the hypothesis that within the same species, the development of a specific model reflects reality more and makes it possible to quantify carbon stocks closer to reality than the generic model.

Keywords: *allometric model; Trichilia Septentrionalis; carbon sequestration.*

INTRODUCTION

Forests, through the natural sequestration of carbon in soils and in forest biomass, actively participate in the fight against climate change. Conversely, their destruction in large tropical forest basins (Amazon, Congo, Indonesia) contributes to the increase in the atmospheric concentration of greenhouse gases.

Deforestation releases the carbon naturally stored in forests but also reduces the overall absorption capacity of the biosphere. It is important to emphasize that one tonne of carbon emitted by deforestation contributes 50% to the increase in the atmospheric concentration of carbon dioxide compared to the emission of one tonne of fossil carbon [3].

Thus, carbon is present in several reservoirs: the Atmosphere, the Pedosphere and the Hydrosphere (which represent all marine or terrestrial ecosystems), the ocean (where carbon is dissolved in the form of CO32- ions, HCO3-), fossil reserves and limestone sediments. Each year, between a quarter and a third of atmospheric carbon changes tanks: it takes less than 5 years for all of the carbon in the atmosphere to be renewed [5].

Carbon sequestration fluxes by a forest follow its life cycle (the carbon stock increases with age before reaching a plateau) and vary according to the climate, the fertility of the sites and the types of stands. It follows from this mechanism that the world's forests contain between 25 and 50% of the carbon accumulated in terrestrial ecosystems (i.e. around 1000-1400 GtC or 2500-4000 GteCO2 of which around 40% in the aerial part by comparison, 760 GtC are found in atmosphere), which are distributed approximately at 49% in the boreal forests, 38% in the tropical forests and 13% in the temperate forests. Tropical forests are also home to 60 to 90% of terrestrial biodiversity [3].

Currently, some African countries do not have forest carbon data and monitoring systems necessary for the establishment of the REDD + mechanism. This aspect of the situation of tropical forests calls on researchers to put in place scientific tools to quantify forest biomass.

The Republic of Guinea has varied ecosystems and receives amounts of rain varying between 2000 and 4000 mm per year depending on the zones. There are sites of great ecological interest, internationally recognized protected areas, the classified forests of Diécké, Ziama de Béro and the Mont Nimba Biosphere Reserve. The Nimba Mountains massif, in the south-east of the Republic of Guinea, was established as a biosphere reserve and a World Heritage site in 1981 with the aim of conserving its ecosystems of extraordinary biological richness [4].

The quantification of these biomass and carbon stocks in tropical forests is essential for the implementation of climate change mitigation strategies, and in particular the mechanism for reducing emissions from deforestation and degradation (REDD +).

Allometric (or biometric) techniques make it possible to estimate the biomass of trees from their circumference, their diameter at 1.30 m (DHH) and their density. There are indeed equations which relate the parameters of trees to their aerial or total biomass (allometric equations)

The development of allometric methods is underpinned by the methodological problems encountered during national greenhouse gas inventories, by the lack or low reliability of the data and by the great uncertainty regarding the accuracy of the results. It is therefore appropriate to base the estimation of the biomass of ecosystems on native (endogenous) allometric regressions, based on a collection of data by slaughter-weighing method.

Thus, the development of methods to quantify, in a reliable and precise manner, carbon stocks and fluxes in tropical forest ecosystems conditions the success of programs to combat climate change such as REDD +. At the tree level, the carbon stock is calculated from the mass or "biomass".

There are two (2) allometric regression models called "pantropical equations" developed by Brown et al. (1989) and Chave et al. (2005)

Until recently, in the absence of locally calibrated allometric equations, pantropical equations were used in tropical Africa. In a first approach, Brown et al. (1989) then Chave et al. (2005) developed pantropical allometric equations separately for “Dry” type forests (rainfall <1500 mm, dry season> 5 months), “Moist” (rainfall 1500 - 3500 mm, dry season 1-5 months) and “ Wet ”(rainfall> 3500 mm, dry season <1 month) [6].

In the Republic of Guinea the Mangrove represents 250,000 ha, the dense humid forest 700,000 ha, the dense dry forest and open forest 1,600,000 ha and the wooded savannah 10,636,000. The Report on the Forest Policy and Forest Action Plan National (2010), the forest heritage amounts to approximately 13,186,000 hectares (or 53.64% of the national territory). The number of classified forests is estimated at 162, for an area of 1,182,133 ha or 8.96 of the national forest reserve [4].

The general objective of this research is to develop a suitable allometric equation model that could allow us to quantify the carbon flows sequestered by the Trichilia Septentrionalis gasoline in the classified forests of Forest Guinea.

This is how the study set itself two (2) specific objectives to achieve:

• Improve knowledge on the dendrometric measurements of Trichilia Septentrionalis;

• Develop an allometric model of the Trichilia Septentrionalis species applicable for independent monitoring and rigorous verification.

II - TOOLS AND METHOD

2.1 - Tools

2.1.1- Description of the study area

Forest Guinea is a natural region of the Republic of Guinea corresponding to the southern part of the country, located between 7 ° 50 'and 10 ° 33' North of longitude and 7 ° 27 'and 8 ° 90' West of latitude and which covers an area of 49,374 km^2 of which Nzérékoré is the main city. This region is essentially mountainous (Mount Nimba peaks at 1752 m with an integral nature reserve). This Mount is classified as World Heritage by UNESCO and covers the main part of the ecotope which shelters more than 200 endemic species: duikers, big cats (lions and leopards), civets, and two species of viviparous amphibians. The Ziama Massif Biosphere Reserve is home to more than 1,300 species of plants and more than 500 species of animals.

The climate is characterized by two rainy seasons of 8 to 10 months (1.5 to 2.6 m of water) between which there is a short dry season where the temperature varies between 24 and 28 ° C; while the humidity remains constant throughout the year. This region, benefiting from a longer rainy season than Middle Guinea and Upper Guinea, is covered with forests [1].

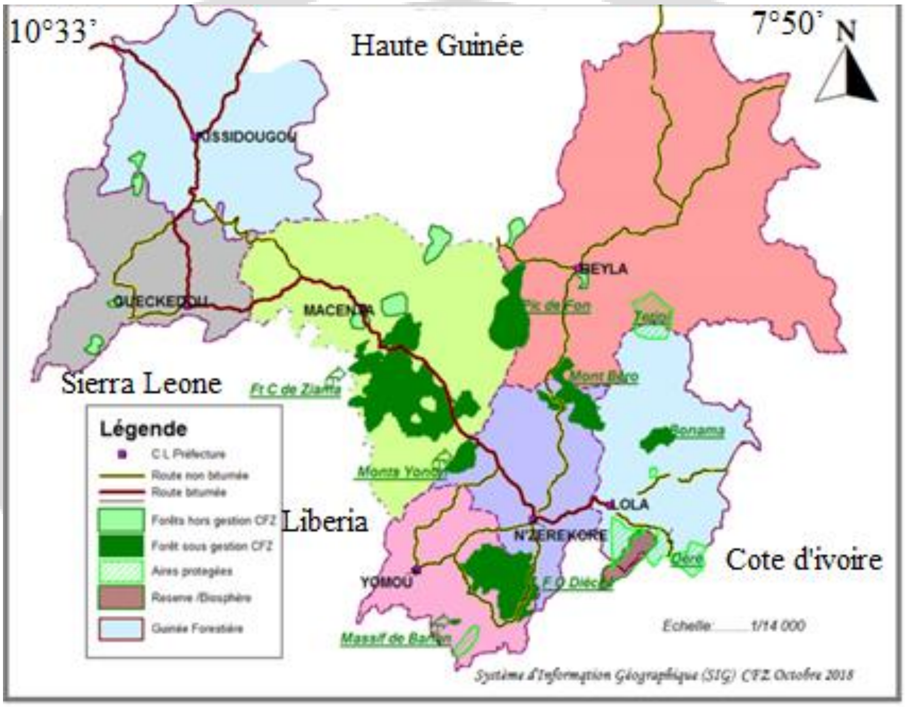

Figure 1 - Map of Forest Guinea (Situation of classified forests)

2.1.2- Allometric equation

To address the development of allometric regressions with biophysical variables as parameters, we will introduce the relationship of proportionality between the relative increases in measurements (Huxley, 1924; Gayon, 2000) which is expressed by:

$$\frac{dB}{B} = a\frac{dD}{D} \text{ [7]} \quad (1)$$

B- the biomass and D- the diameter

Thus, there is a coefficient a in this relation which will make it possible to establish a relation of power such as:

$$B = b.D^a \quad (2)$$

2.1.3- Types of allometric equations

. It's about :

- **Single-species or genus-specific equations**, for example those established by Basuki et al. (2009) for four genera of commercial species in Indonesia; these equations generally include the diameter and / or the height, and possibly the age of the stand for plantings in the game of predictors;

- **Local multi-species equations** established in a given site which include the diameter and / or the height, and the density of the wood in the game of predictors;

- **Regional or pantropical multi-species equations with diameter** and / or height, wood density and forest type in the game of biomass predictors; the main pantropical equations are those of Brown et al. (1989), de Chave et al. (2005), de Feldpausch et al. (2012); they are carried out globally, then by type of forest (distinguishing three tropical forest types: "wet" - "moist" - "dry") [3].

2 Dendrometric measurements

To perform the dendrometric measurements, six parameters will be measured at the level of the standing trees: Total height of the tree - H (m); trunk height - Ht (m); Diameter at the base - Db (cm); Diameter at Chest Height (1.3 m) - DHH (cm); Circumference at the level of the DHP -C (cm) and Width of the crown - Lh (m).

To analyze the data collected in the field, two software programs were used: the "R" software and the "Excel" software. These spreadsheets allow you to quickly enter data in tabular form, display it in various graphs, and apply regressions.

Arithmetic operations, graphs performed and modeling of the linear regressions for confidence intervals around these regressions was carried out.

2.2- Methodology

The methodological approach is illustrated by the figure below

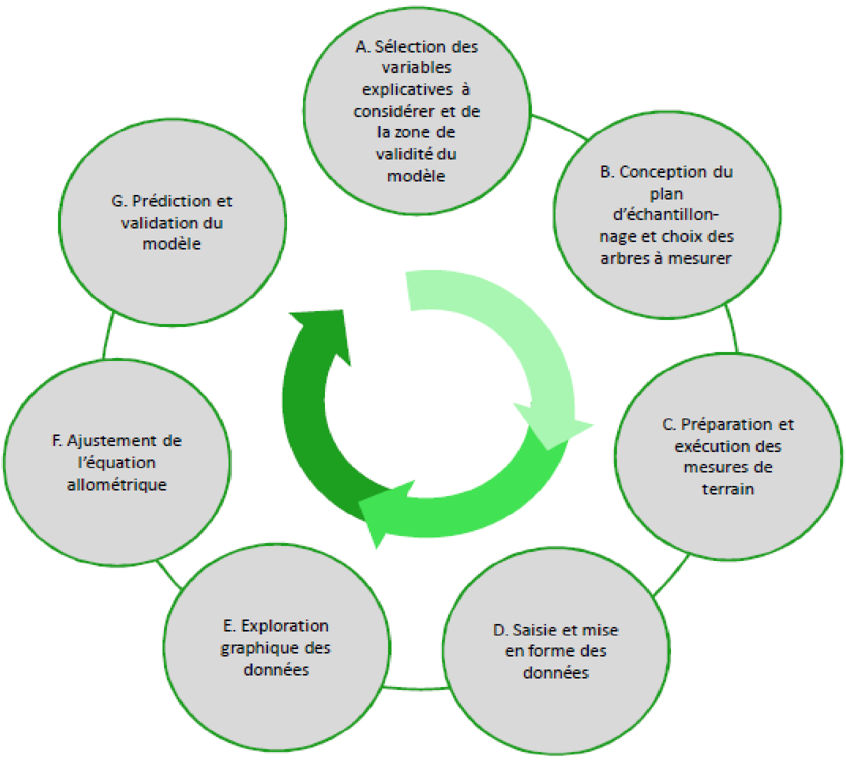

Figure 2 - Diagram of the different stages of the method [2]

2.3- Data collection

The individuals were selected on the basis of their health, their distance from each other, the geomorphology of the environment and their diameter at breast height on radiographic transects. A total of 375 individuals were used in the process of developing the allometric equations.

The diameter at breast height of the subjects was between 8.5 and 43.9 cm and the height between 4.2 and 15.1 m. The following biomass measurements were made on the selected tree samples: the diameter at breast height (DHH) (1.30 m from the ground), the two crossed crown diameters (d1 and d2) and the total height (H). The determination of dry biomass (Ms) of small sample was determined. The biomass conversion rate for each compartment, branches and leaves was calculated on the basis of formula (3).

3 - RESULTS AND DISCUSSIONS

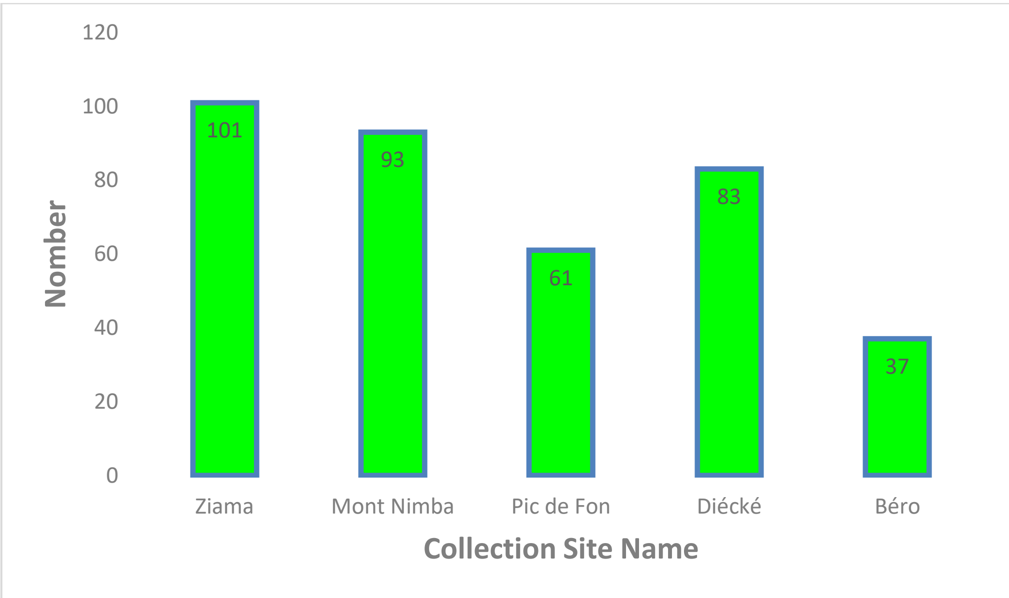

Figure 3 - Classification of the species Trichilia Septentrionalis according to the zones

It appears from figure (3) that the collected Trichilia Septentrionalis species is more important in the areas of Ziama, Mont Nimba and Diécké and less in Béro and Pic de Fon.

3.1- Dendrometric measurements

The weight of the biomass is respectively higher in the trunk, twigs, branches and stems (Table 2). Thus, lignification is more important in the trunks than the other parts of the tree.

Table 1 - Distribution of the weight of the tree's biomass

Variables	**Weight of dry matter**			
	Stem (kg)	**Branchs (kg)**	**Trunk (kg)**	**BS total (kg)**
Minimum	25,86	48,78	104,33	178,71
Maximum	78,56	98,12	124,31	300,99
Average	52,21	73,45	114,32	7461,53

Several allometric equations were tested in order to retain those which seem more explanatory of the aboveground biomass as a function of the dendrometric parameters. The first criteria for eliminating the models were the coefficient of determination R2 and the overall significance of the equation generated by the Software R. Thus, the following models were retained

- Linear model with additive error effect:

$$B = \beta_0 + \beta_1 D_1 + \ldots\ldots\ldots + \beta_p D_p + \varepsilon \quad (3)$$

- Non-linear model with additive error effect:

$$B = \beta_0 D_1^{\beta_1} D_2^{\beta_2} + \ldots\ldots\ldots + D_p^{\beta_p} + \varepsilon \quad (4)$$

- Nonlinear model with multiplicative error effect:

$$B = \beta_0 D_1^{\beta_1} D_2^{\beta_2} \ldots\ldots D_p^{\beta_p} \varepsilon \quad (5)$$

With Di the variables measured on the tree βi, the coefficients to be estimated and ε the error term. The logarithmic transformation of the nonlinear model with multiplicative error effect results in a linear model with additive error effect. He writes:

$$\ln(B) = \ln(\beta_0) + \beta_1 \ln(D_1) + \ldots\beta_p \ln(D_p) + \ln(\varepsilon) \quad (6)$$

after logarithmic development and adjustment, ten (10) regression models were obtained according to the biomass see table 2.

Table 2 - Predictive models of allometric equations for dry biomass. The coefficients β_1, β_2 et ε are the adjusted parameters of the models. CSR-Residual standard error and AIC - Akaike's information criterion

N°	Models	ε	β_1	β_2	RSE	AIC
1	$Log(B) = \ln(\varepsilon) + \beta_1.Log(D)$	-1,5	2,4	-	0,33	44,6
2	$Log(B) = \ln(\varepsilon) + \beta_1.Log(D).\beta_2.Log(D^2)$	-1,5	2,4	-0,03	0,33	45,1
3	$Log(B) = \ln(\varepsilon) + \beta_1.Log(D).\beta_2.Log(D^2).\beta_3 Log(D^3)$	19,6	-15,3	4,85	0,33	45,12
4	$Log(B) = \ln(\varepsilon) + \beta_1.log(D).\beta_2.log(\rho)$	-1,18	2,36	0,87	0,29	30,71
5	$Log(B) = \ln(\varepsilon) + \beta_1.log(D).\beta_2.log(D^2).\beta_3 log(\rho)$	-0,85	2,21	0,02	0,29	31,23
6	$Log(B) = \ln(\varepsilon) + \beta_1.log(D).\beta_2.log(D^2).\beta_3 log(D^3).\beta_4 log(\rho)$	7,99	-5,17	2,05	0,29	32,01
7	$Log(B) = \ln(\varepsilon) + \beta_1.log(D).\beta_2.log(H)$	-3,37	1,86	1,12	0,29	28,94
8	$Log(B) = \ln(\varepsilon) + \beta_1.log(D^2.H)$	-3,15	0,97		0,29	2,47

9	$Log(B) = \ln(\varepsilon) + \beta_1.log(D).\beta_2.log(H).\beta_3 log(\rho)$	-2,34	2,11	0,64	0,26	18,9
10	$Log(B) = \ln(\varepsilon) + \beta_1.log(D^2.H).\log(\rho)$	-2,77	0,95	0,69	0,26	16,91

Among the ten (10) models, six (6) equations take into account the diameter and density and among these models the best model is the one with an AIC of 30.71 and a CSR of 0.2989. He writes:

$$B = \exp\left\{\left(-1{,}18172.D^{2,56}.\rho^{0,97}\right).\left(\frac{(0,2989)^2}{2}\right)\right\} \quad (7)$$

On the other hand, only four equations taking into account the diameter, the height and the density were developed, among which the model 10 is the best, with an AIC of 16.91 and a RSE of 0.26. He writes:

$$B = \exp\left\{\left(-2,7745.\left(D^2.H\right)^{0,98}\right).\rho^{0,78}\left(\frac{(0,2989)^2}{2}\right)\right\} \quad (8)$$

The criteria for selection and validity of the models are based first of all on the tests of normality, nullity, heterogeneity and autocorrelation of the residuals. Then, the error analysis is performed, in particular the residual error, the standard residual error (CSR) and the Akaike information criterion (AIC).
The models chosen are the most suitable for the different zones because they have less bias for large diameters and predict small subjects well. In most cases, the large diameter biomass is slightly underestimated. It poses fewer problems in terms of calculating additionality than in the case of overestimation for which one claims to account for more carbon than reality.

4- Discussion of prediction and adjustment results

The values of the mean absolute relative error of prediction show that the relative bias is large (greater than 32%). It is of the same order of magnitude as that found by Ngomanda et al. (2014) namely 35-47%. The quality of the equation depends on the representativeness of the data across a fairly wide diameter range and the sample size (equation 6).
Indeed, the models of Chave et al., of the "moist" type are the best, being established with a large number of data (1506 and 1348 for equations 6 and 10 respectively). These results confirm the limits of local equations (notably equation (8) generally carried out on a reduced number of tree samples and on a restricted range of wood density. From the analysis of the prediction results, we can learn two basic lessons:

- The existing local equations make it possible to achieve the necessary precision to dispense with the pan tropical equations of Chave et al;
- A wide range of diameters is required to ensure better quality of the equations.

From the analysis of these adjustment results, in the context of researching the form of the model, it appears necessary to start from a general model with the different predictors as applied in the work of Chave et al. (20014) and Ngomanda et al. (2014) ; then by the regressive selection method, find the best with scenarios.
It should be noted that Jérôme Chave suggests using the "wet forest" model in tropical rainforest, which means "rainy forest" if the total height of the trees is available… biomass of tropical rainforests Equation Model of regression Chave et al. 2014.

- **Selection of allometric equations**

In the selection of allometric equations, equation (7) has a residual error and a high AIC. While equation (8) has a residual error equal to 0.044 or 4.43% and a lower AIC compared to equation (7). This means that the power model is more explanatory for the aboveground biomass of the species Trichilia Septentrionalis in Forest Guinea.

CONCLUSION

The study of the test for the development of multi-species allometric equations of some forest species in Guinea, allowed us to develop an equation which allows to estimate the level of carbon sequestration by a specific forest species.

To assess forest carbon emissions, several allometric models have been developed to take into account the carbon dimension in forest ecosystems. Despite these efforts, few studies have made reference in Africa and particularly in the classified forests of the Republic of Guinea.

Estimating the amount of carbon sequestered by woody vegetation requires the establishment of a consistent and precise calculation base. The development of a specific model is justified in more ways than one. Indeed, many allometric models used so far do not take into account the specificities of the species. For the estimation of the carbon of a specific stand, we consider that 40 - 50% of the dry biomass consists of carbon in the woody vegetation.

The application of the models to the inventory data of the chronosequence of the classified forests Ziama, Mont Nimba, Boré, Pic de Fonc and Diécké shows that the tools currently used in practice (Bouchon, 1982) greatly underestimate crown stocks which nevertheless represent the main part of the biomass potentially usable for wood energy needs. For the estimation of forest carbon stocks at the national level, the use of biomass equations gives more precise results (10%) than the successive estimation of a volume and then of a mass.

The criteria for selection and validity of the models are based first of all on the tests of normality, nullity, heterogeneity and autocorrelation of the residuals. Then, the error analysis is performed, in particular over the residual error, the standard residual error (CSR) and the Akaike information criterion (AIC).

Among the ten (10) models, six (6) equations take into account the diameter and density and among these models the best model is the one with an AIC of 30.71 and a CSR of 0.2989.
On the other hand four (4) equations taking into account the diameter, the height and the density were developed, among which the model 10 is the best, with an AIC of 16.91 and a RSE of 0.26. He writes:
Equation (8) has a residual error equal to 0.044 or 4.43% and a lower AIC compared to equation (7) which has a high residual error at the same time as the AIC. This means that the power model is the most explanatory of the aboveground biomass of the species Trichilia Septentrionalis in Forest Guinea.

For this purpose, equation (8) is developed for the species of classified forests in Forest Guinea under a Subequatorial climate type. These results could be used to assess the amount of atmospheric carbon sequestered by these species and help decision-makers to make policy decisions on adaptation to climate change.
In addition, these results could stimulate the introduction of the species into agro forestry practices with the aim of capturing carbon in order to reduce greenhouse gas (carbon) but also to provide income for rural producers in the carbon market framework.

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