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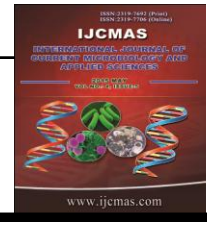

Original Research Article

Estimate trees potential and wood cubage in natural stands of *Pterocarpus erinaceus* Poir. based on ecological gradient in West Africa

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A B S T R A C T

*Pterocarpus*is one of the most exploited tree species in many countries in West Africa. Planks and logs have been exported towards the South-West Asian countries for ten years. This study is conducted to make available to the forest administrations of West African countries, the tools to enable them quantify quickly the potential of *P. erinaceus* wood products in natural stands in the Guinean-Sudanian-Sahelian (GSS) zone. The data for the development of the volume cubage and the quantification of *P. erinaceus* tree potential were obtained through forest inventories in Burkina Faso, Niger and Togo. Some results show that *P. erinaceus* stands available in the three (3) climate zones indicate that the tree average density ranges between 1.17±0.75 stems/ha (Sahelian zone) and 74.9±1.4 stems/ha (Guinean zone). The densities values vary significantly from one climate zone to the other ($P<10^{-3}$). For the average tree diameter, the values range between 22.07±8.98 (Guinean zone) and 49.63±19.44 cm (Sahelian zone), with substantial variability (CV = 53.6%) in the Sudanian zone. A significant difference was also noted for this parameter inside the three zones (P<0.001). Regarding the basal area, the values obtained range between 0.30±0.30 (Sahelian zone) and 3.15±1.30 m²/ha (Guinean zone). The difference observed inside the three zones is statistically significant (P <0.001).The analysis of the average total height and merchantable height of *P. erinaceus* stands shows various values depending on whether it is in the Sahelian zone, Sudanian zone or Guinean zone. For the average total height, the stands of the Sudanian zone (9.51±2.8 m) are significantly different (P<0.001) from the other two zones (10.18±2.27 m for the Sahelian zone and 10.09±2.88 m for the Guinean zone). Considering the merchantable height, it ranges between 4.08±1.35 m (Sahelian zone) and 2.58±2.63 m (Guinean zone). For this parameter, the difference observed inside the three zones is statistically significant (P <0.001; Table 2). Among the various models designed for *P. erinaceus* (power, quadratic, linear, polynomial models), only the "power" models present the low values of Akaike (AIC). These models account respectively for 73.9% (Sahelian zone), 86.15% (Sudanian zone) and 82.82% (Guinean zone) of the variability with the respective residual standard deviation of 1.006, 1.001 and 1.013. The regression coefficients "a" and "b" are significant for the power models (P <0.001). The significance tests of the established models show that these models are globally satisfactory (P <0.001). In view of all these results, the power models appear to be most suitable for the GSS zone.

Keywords

Guinean-Sudanian-Sahelian Zone, Pterocarpus erinaceus, volume cubage, power models

Introduction

Exploitation of forest product sin the African tropical forest focuses on a limited number of quality timber species often exploited in fraudulent manner without any compliance with the management principles (Ristet al., 2012; Adjonou et al., 2010; Ganaba et al., 1998). *Pterocarpus erinaceus* is one of the most exploited species inmany West African countries. It is an endemic species of the Sahelian and Sudanian tropical zones (Syllaet al., 2002), where the natural stands are encountered in wood land savannahs and dry forests. The wood from this species is highly valued in cabinet work and in many other fields of activity.

In the sub-region, a large quantity of the *Pterocarpus* planks and logs has been exported towards the South-West Asian countries for ten years. It is highly sought after for the high quality fodder with an average dry matter nutritional value for livestock (Anderson et al., 1994). This fodder is more and more found on urban and semi-urban markets for sale, especially during the dry season. The sellers of *P. erinaceus* fodder are henceforth forced to travel over tens of kilometers to find trees that are still bearing leaves at harvest (Bonkoungou et al. 1998). The species is also one of the best crafts wood (Touré, 2001), used in sculpture, joinery and especially for the exported wood. *P. erinaceus* then appears as an endangered species in all the forest zones and the agro-forestry parks of the Sudanian-Sahelian (SS) and Sudanian zones (Nacoulma, 2012; Gaoué and Ticktin, 2007; Devineau, 1999).

Unfortunately, the market value of the timber and other derivatives are poorly estimated by the managers. This situation leads to controversies between the administration and the operators who must pay relevant penalties for quotao verruns (Tchatatet al., 2008). Lack of technical bases and appropriate data such as dendrometric data (Akinsanmi and Akindele, 1995; Fonton et al., 2009) required for the estimation of wood resources account for the afore-mentioned situation. Indeed, one of the main objectives of the dendrometric studies is undoubtedly the wood cubage development (Fayolle et al., 2013). These cubage help estimate the volume of a tree based on one or more directly measurable dendrometric characteristics on the field such as the diameter and height of the trees (Lanly, 1965; Cailliez, 1980; Rondeux, 1999, Brown et al., 1989). The trees volume tables for a stand are key tools for the forest management and inventory because they help achieve quick estimation of the trees volume (Pardé and Bouchon, 1988; Rondeux et al., 1991; Fonweban and Houllier, 1997).

This study was conducted to make available to the forest administrations of the West African countries, appropriate tools to enable them quickly quantify the potential of *P. erinaceus* wood products in the Guinean-Sudanian-Sahelian (GSS) zone. Specifically, it is about 1)- providing suitable volume scaling of *P. erinaceus* in West Africa and 2)- assessing the available commercial wood volume to provide forest managers with tools and indicators on the wood potential for the development of the consequent forest management plan and the consistent planning of *P. erinaceus* products exploitation.

Materials and Methods

Study zone

The data collection is carried out in three West African countries located in the GSS climate zones and in different ecological conditions (Figure 1). These include Burkina Faso, Niger and Togo. The main ecological characteristics of the study area are as follows:

Southern and Central Togo characterized by a rainfall ranging between 800 and1600 mm/year. The average temperature varies between 26-28°Cin the plains and falls down to 24°Cin altitude. The relative average humidity varies between 70 - 90%. The soils encountered were mainly tropical ferruginous, shallow soils with vertisols, ferrallitic and hydromorphic. The main plants communities identified were guinean woodlands, open woodlands, gallery forests, moist and semi deciduous forests, crops and fallows, thickets, derived savannahs, coastal grass savannahs, savannahs on termite mounds, mangroves;

Northern Togo is characterized by a rainfall rangingbetween1000 and 1300mm/year. The relating average humidity ranges from 50 to70%. The soils are of ferruginous tropical type. In this zone, the dominant plants communities are Sudaniansa vannahs, gallery forests, steppic savannahs, mosaics of dry deciduous forests, grass savannahs and woodland savannahs;

In Burkina Faso, two ecological zones were part of the study areas. The first part in the South is located between 9°20’ et 11°30' of North latitude, with a rainfall between 900 and1200 mm and an average annual temperature of 27°C. The second zone in the North is located between 11°30'and 14° of North latitude, with a rainfall ranging between 600and 900mm/year and an average annual temperature of 28°C.Therelative average humidity ranges from 25 to85%in the South and23-75% in the North. The ferric soils encountered were generally infertile (Ouattara et al., 2006). The main plants communities were clear savannah woodlands, shrub savannahs, grass savannahs, open savannahs, open forests and gallery forests.

In Niger, the wildlife reserves of Tamou, Gaya and the Wpark were considered. The average annual rainfall was 606mm and the average annual temperature was around36.7°C. In this zone, the dominant plants communities identified were shrub savannahs, grass savannahs, woodland savannahs and open woodlands.

Considering these pieces of information, the study area is divided into 3 climate zones(Guinean zone, Sudanian zone and Sahelian zone), taking into account the classification of Hountondji (2008), based on the total annual classes of rainfall:

- Total annual rain fall ower than 700: Sahelian zone including the Tamou wildlife reserve and the Wpark in Niger;
- Total annual rainfall ranging between 900and 1200mm: Sudanian zone including the forests of Tiogo, Saponé, Cassou, Laba, Comoé-Léraba in Burkina Faso, but also the ecological zones I and II in Togo and the forest of Gaya in Niger;
- Total annual rainfall higher than 1200mm:Guinean zone including the ecological zones III, IV and V in Togo.

Data collection

Data for the development of the volume cubage and the quantification of *P. erinaceus* tree potential were obtained through forest inventories in three countries namely Burkina Faso, Niger and Togo. The sampling is based on two methodological approaches namely the transect method (in the Sudanian-Sahelian (SS) zones of

Burkina Faso and Niger) and the random method (Guineo-Sudanian (GS) zones of Togo). The choice of the transect method is explained by the low density of *P. erinaceus* in the natural stands of the SS zones of Burkina Faso and Niger, while the random method is adopted for the zones with a relatively high density of the species. For the first method, the sampling focuses on the transects of about 200 m width and a variable length based on the density and surface of the covered sites (Assogbadjo et al., 2005; Assogbadjo et al 2009).

The use of the two North-South and East-West transects helps taking into account the heterogeneity of the stands studied and making sufficiently inventories of *P. erinaceus* trees for a good representation of the sampling. The azimuth methodology was carried out using a GPS while the distance to the tree was estimated using a laser range-finder to avoid the tree to be beyond 100 m. The starting point and the end point coordinates were recorded and the distance covered was estimated by the GPS. Regarding the random method, it is based on the location of observation plots of 1000 m² (40 m x 25 m) randomly defined in the stands dominated by *P. erinaceus* at regular intervals of 200 m. This forest inventory method with unit plots of 1000 m² as sampling unit was already used by SPIAF (2007).

For both methods, all *P. erinaceus* trees with a diameter more than 10 cm (DBH≥ cm) were measured. This concerns stems diameter of 1.30 m from the ground (D), at the foot base above the buttress (d_1) and the diameter at the base of the first branch (d_2) and finally the height of the stem (s), respectively, using a tree caliper and a graduated pole (for less than 5 m height trees) or a Bitterlich Relascope (tree height of more than 5 m). Therefore, a total of 2114 trees were measured, 203 individuals in the Sahelian zone, 1546 individuals in the Sudanian zone, 365 individuals in the Guinean zone were used for the design of the volume cubage models. Rondeux (1999) recommended a sample of 30 to 100 trees per homogeneous stand to validate a model of volume cubage.

Data analysis and processing

Determination of the merchantable volume

The volume considered in this study corresponds to the volume of the stem over the bark of the tree from the birth of the buttresses (cutting height) and deformation due to the first branch (Lanly, 1965). The two diameters (d_1 and d_2) and the height of the stem collected on *P. erinaceus* trees helped to determine the volume of each tree stem. The volume of the stem (Vf) of the tree *i* is determined using the formula of Smalian as follows:

$$V_{fi} = \frac{\pi}{4} li \left(\frac{d_{1i}^2 + d_{2i}^2}{2}\right)$$ with d_{1i} et d_{2i}= diameters of the two ends of the tree *i*, *li* = trunk height of the tree *i*. This formula based on the non-destructive methods (Fonton et al., 2009) helps estimate the wood volume of standing trees knowing the two extreme diameters unlike the destructive method (Fayole et al., 2013) or by successive log.

Design of Wood Volume Models

The volume cubage developed is designed according to two methods namely the graphical method and the application of statistical regression method. In the graphical method, the trees are all positioned on a graph which respectively materializes the volume on the ordinate and the diameter on the abscissa. The result is a scatter chart representing the projection of each timber individual in the orthogonal plan.

Regarding the statistical regression method, in general, two equations linking the volume to the diameter are used: linear relationships of polynomial and nonlinear relationships of exponential model (Picard et al., 2012). Therefore, the tested volume cubage' models are one entry volume. The reasons for these choices lie in the fact that in most natural stands investigated the fodder of *P. erinaceus* has been exploited by means of pollarding and considering the height could be bias taking into account the models. Therefore, only the volume of the stem and the diameter were considered. It is about the following linear and non linear models:

- Power: $Vf = aD^b$;
- Linear: $Vf = a + bD$;
- Quadratic : $Vf = aD^2 + b$;
- Polynomial of degree 2: $Vf = aD^2 + bD + c$.

Strictly speaking, the volume cubage applies only for the species, the range of diameters and the geographical zone of the trees being used for the design (Rondeux, 1999). In addition, they should be systematically matched with the parameters helping to calculate estimates of confidence margins (Picard et al., 2012). To do so, the regression analysis was performed with the stem volume data based on the diameter of 1.30 m above the ground. The Durbin Watson test was used to check the autocorrelation of the studentized residuals, selected by cross-validation. The distribution of these residuals around Henry's right was analyzed after a Ryan-Joiner test. The compliance test of an average was used to check whether the residual average is zero. Finally, the test of Breush-Pagan made it possible to analyze the residual heterocedacity. The value of the aIkaike Information Criterion (IIC/AIC) was determined for each of the established models. All these tests were carried out for power models after the logarithmic transformations of the stem volume and the diameter in order to streamline the models. The model then obtained is of the types $\ln(Vf) = \ln a + b\ln(D)$. The regressions and all statistical analyses were carried out using the free software R (R Development Core Team, 2013) and Minitab16 program.

Selection of the best models and validation criteria of the models

Each of the designed models was adjusted and the quality of the adjustment was assessed from the coefficient of determination (R^2), the residual standard deviation (*RSE*) and the significance of the model (Probability or p-value). The criterion of Akaike (AIC) was used to select the best model. The AIC penalizes the likelihood of the model by the number of parameters, and therefore allows to avoid over parameterization. Graphics were used to examine the distribution of each model residual. 95% confidence intervals are provided for each model parameters.

Quantification of *P. erinaceus* wood volume

The overall estimated merchantable volume of *P. erinaceus* per hectare is based on the models of volume cubage designed for each climate zone while respecting the diameter classes.

Result and Discussion

Variability of *P. erinaceus* stands dendrometric characteristics

Analysis of the main characteristics of *P. erinaceus* stands in the three (3) climate zones indicates that the tree average density ranges between 1.17±0.75 stems/ha (Sahelian zone) and 74.9±1.4 stems/ha

(Guinean zone). The values of densities vary significantly from one climate zone to the other ($P<10^{-3}$). For the average tree diameter, the values range between 22.07±8.98 (Guinean zone) and 49.63±19.44 cm (Sahelian zone), with substantial variability (CV = 53.6%) in the Sudanian zone. A significant difference was also noted for this parameter inside the three zones (P<0.001). Regarding the basal area, values obtained range between 0.30±0.30 (Sahelian zone) and 3.15±1.30 m²/ha (Guinean zone). The difference observed inside the three zones is statistically significant (P <0.001) (Table 2).

The analysis of the average total height and merchantable height of *P. erinaceus* stands shows various values depending on whether it is in the Sahelian zone, Sudanian zone or Guinean zone. For the average total height, the stands of the Sudanian zone (9.51±2.8 m) are significantly different (P<0.001) from the other two zones (10.18±2.27 m for the Sahelian zone and 10.09±2.88 m for the Guinean zone). Regarding the merchantable height, it ranges between 4.08±1.35 m (Sahelian zone) and 2.58±2.63 m (Guinean zone). For this parameter, the difference observed inside the three zones is statistically significant (P <0.001; Table 2).

Variability of the tree densities within the diameter classes

The distribution of the tree diameter classes leads to the following observations:

In the Sahelian zone, the distribution reveals a predominance of the tree diameter classes ranging between 30 and 65 cm, i.e., 55.09% of the stand. The young trees (10 and 30 cm) and larger trees (65 and 100 cm) are very less represented, respectively 11.13 and 29.77% of the stand (Figure 2);

In the Sudanian zone, there is a predominance of the tree diameter classes ranging between 15 and 40 cm, i.e., 74.4% of the stand. The young trees DBH between 10 and 15 cm and larger trees DBH between 40 and 95 are poorly represented, i.e., respectively 17.11% and 8.4 of the stand;

The Guinean zone is characterized by a preponderance of the tree diameter classes ranging between 10 and 25 cm, i.e., 69.10% of the stand. The tree diameter classes larger than 25 cm are poorly represented, i.e., 30.8% of the stand (Figure 2).

Models of the volume cubage

The various models designed for *P. erinaceus* in the GSS zone indicate that the best regression models obtained regardless of the climate zone, which fit significantly are the power-type (Table 3). Indeed, for the four models tested (power, quadratic, linear, polynomial), only the "power" models present the low values of Akaike (AIC). These models account respectively for 73.9% (Sahelian zone), 86.15% (Sudanian zone) and 82.82% (Guinean zone) of the variability with respective residual standard deviation of 1.006, 1.001 and 1.013 (Appendix 1). The regression coefficients “a” and “b” are significant for the power models (P <0.001). The significance tests of the established models show that these models are globally satisfactory (P <0.001). However, it should be noted that the quadratic and polynomial models fit relatively well with data including determination of coefficients higher than 70% and a residual standard deviation ranging from 0.74 $m^3$to 1.032 m^3 (Table 3).

In view of all these considerations, the power models appear to be most suitable for GSS zone.

The corresponding equations for each zone are expressed as follows (Figure 3):

Vf = 3.1917 $D^{1.8748}$ (Sahelian zone);
Vf= 3.0195 $D^{2.068}$(Sudanian zone) and;
Vf = 2.3497 $D^{2.1082}$(Guinean zone).

Volume of *P. erinaceus* tree available

Analysis of *P. erinaceus* wood volume estimated in the GSS zone indicates that the most important value of the wood volume per hectare is obtained in the Guinean zone over 7.27 m^3/ha. In the other two zones, the wood potentials in *P. erinaceus* are close with an estimated volume of 1.5 m^3/ha in the Sahelian zone and 1.1 m^3/ha in the Sudanian zone. These differences may be explained by the fact that in the Sahelian zone, only larger diameter trees (average diameter of 49.63±19.44 cm) remain; while in the Sudanian zone, the frequency of the young individuals is more important (average diameter of 29.02±15.44 cm) (Table 2).

The analysis of the wood volume distribution in terms of diameter classes indicates that at the level of the Guinean zone, the wood volume is concentrated in the diameter class ranging between 20 and 40 cm and between 25 and 50 cm in the Sudanian zone. The volume of timber appears much more concentrated in the diameter class ranging between 50 and 75 cm for the Sahelian zone (Figure 4).

The volume cubage is in general regionalized and is more efficient when it is defined according to the homogeneous ecological zones, i.e., when taking into account the phyto geographical, climate, geologic and pedologicdata (Fayolle et al., 2013, Henry et al., 2011, Zianis et al., 2005). This stage is important to define the application zone of a technically robust volume cubage.

Of all the models tested the "power" models appear as the most adapted to the three zones. This result is confirmed by the volume cubages developed in West and Central Africa in the context of the logging industry (Mayaka et al., 2014). Indeed, Fayolle et al., (2013) estimated that the volume cubage of the power form, and with single entry seems to be the most robust and easiest to use by forest managers and allowed to estimate the volume of timber from the inventory data, unlike the two-entries models that incorporate the diameter at 1.30 m from the ground and the height of the stem (Fonton et al., 2009).

Table.2 Main forest characteristics of the three climatic zones

Climatic zones	**Density (tree/ha)**		**Average diameter (cm)**		**Average height (m)**		**Average commercial height (m)**	
	Avg±SE	CV (%)	Avg ± SE	CV (%)	Avg±SE	CV (%)	Avg±SE	CV (%)
Sahelian	1,17±0,75	64,1	49,63±19,4	39,2	10,18±2,3a	22,29	4,08±1,4	33,1
Sudanian	35,05±41,2	117,5	29,02±15,4	53,2	9,51±2,8	28,91	3,63±1,5	41,1
Guinean	74,9±1,4	1,92	22,07±8,9	80,7	10,09±2,9a	28,54	2,58±2,6	101,9
Probability	<0,001		<0,001		<0,001	<0,001		

NB: Avg. = Average; SE: Standard error; CV: Coefficient of variation

Table.3 Models established for P. erinaceus in climatic zones

Climatic zones	Equation	Probability	Conformity test			R^2	Residual standard deviation	AIC
			a	b	c			
Power model								
Sahelian zone	$Vf = 3{,}1917\ D^{1,\ 8748}$	**<0,001**	<0,001	<0,001	-	**73,9**	1,006	**165,3629**
Soudanian zone	$Vf = 3{,}0195\ D^{2,\ 068}$	**<0,001**	<0,001	<0,001	-	**86,15**	1,001	**-1139,003**
Guinean zone	$Vf = 2{,}3497\ D^{2,\ 1082}$	**<0,001**	<0,001	<0,001	-	**82,82**	1,013	**-1125,431**
Quadratic model								
Sahelian zone	$Vf = 3{,}6223\ D^2$	<0,001	-	<0,001	-	73,32	1,021	325,6718
Soudanian zone	$Vf = 4{,}3583\ D^2 - 0{,}1133$	<0,001	<0,001	<0,001	-	80,85	0,746	-310,359
Guinean zone	$Vf = 2{,}1496\ D^2$	<0,001	-	<0,001	-	76,8	1,024	-1085,841
Linear model								
Sahelian zone	$Vf = 4{,}6577\ D - 1{,}3714$	<0,001	<0,001	<0,001	-	69,51	1,017	352,9121
Soudanian zone	$Vf = 2{,}4114\ D - 0{,}3804$	<0,001	<0,001	<0,001	-	67,33	1,013	-355,0826
Guinean zone	$Vf = 1{,}1542\ D - 0{,}1324$	<0,001	<0,001	<0,001	-	74,99	1,020	-1057,309
Polynomial model								
Sahelian zone	$Vf = 4{,}5124D^2 - 1{,}118\ D + 0{,}3123$	<0,001	<0,001	0,299	0,348	73,48	1,028	326,5762
Sudanian zone	$Vf = 5{,}0622D^2 - 1{,}0261\ D + 0{,}1062$	<0,001	<0,001	<0,001	<0,001	80,08	1,012	-1124,184
Guinean zone	$Vf = 1{,}5219D^2 + 0{,}3457\ D - 0{,}0402$	<0,001	<0,001	0,0130	0,0202	77,19	1,032	-1090,071

NB: AIC: Akaike Information Criterion; P (p-value): significance of the model; R^2: coefficient of determination; a, b, c: regression coefficients

Figure.1 Study area location

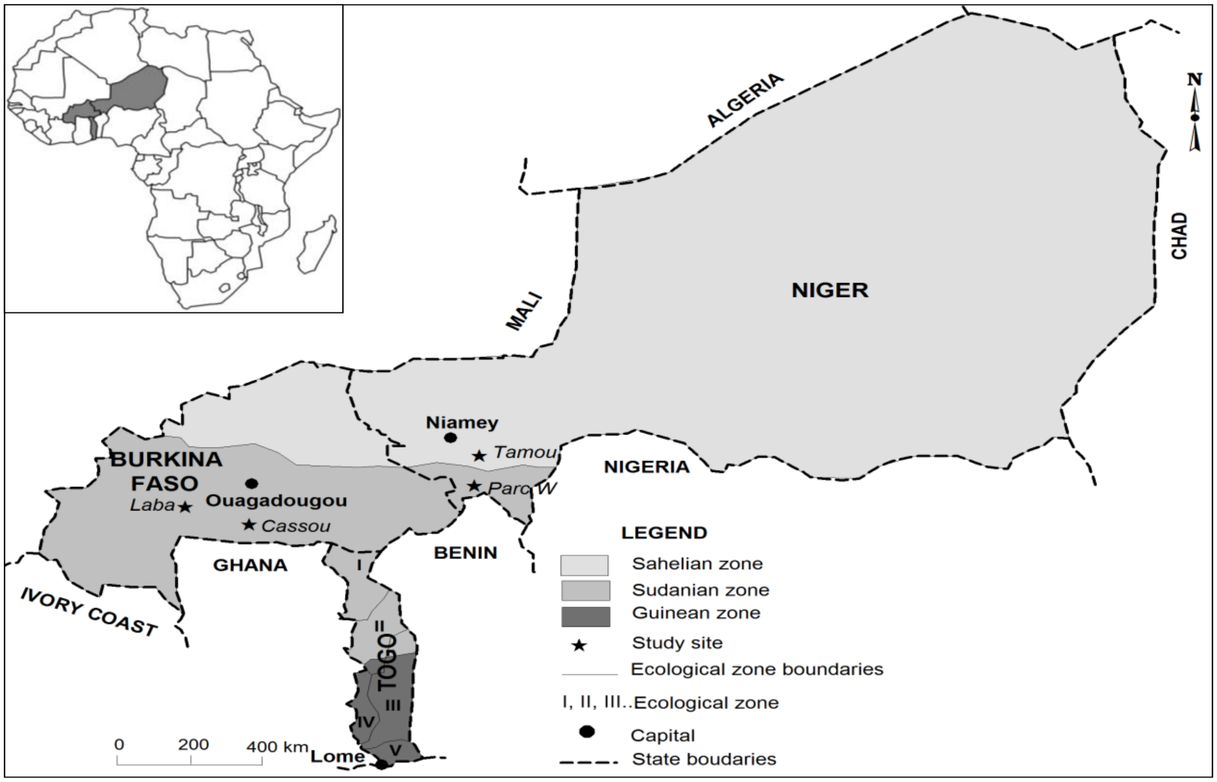


Figure 2: Demographic structures of stands across the climatic zones

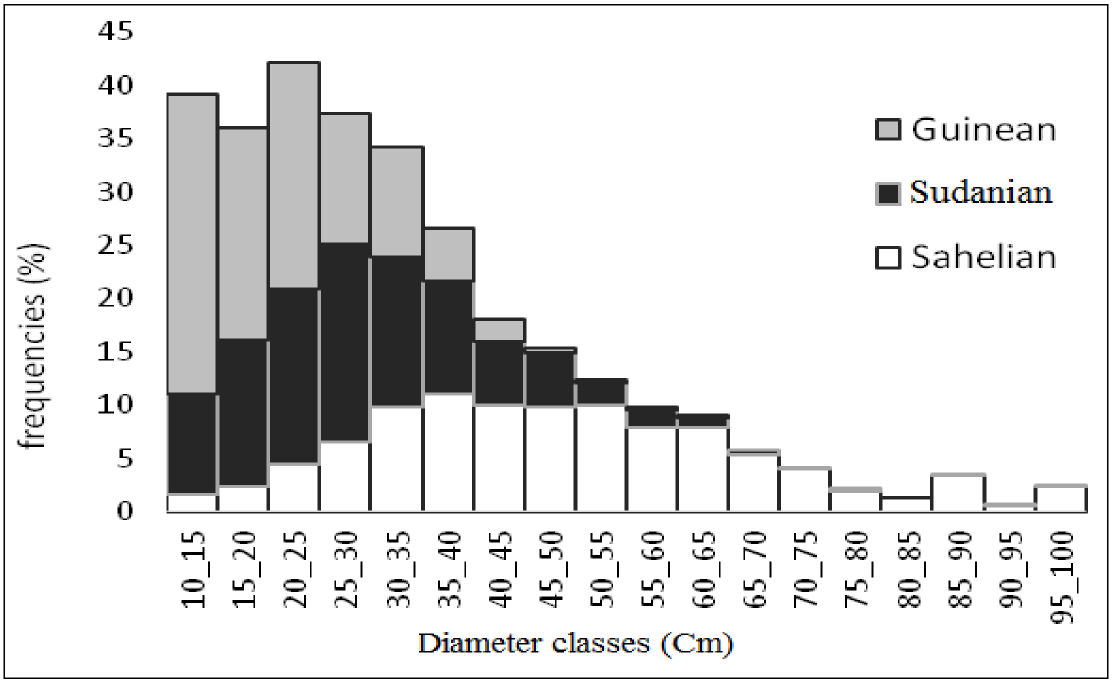


Figure.3 Volume cubage models of *P. erinaceus* across climatic zones: A: Sahelian zone; B:Sudanianzone; C: Guinean zone

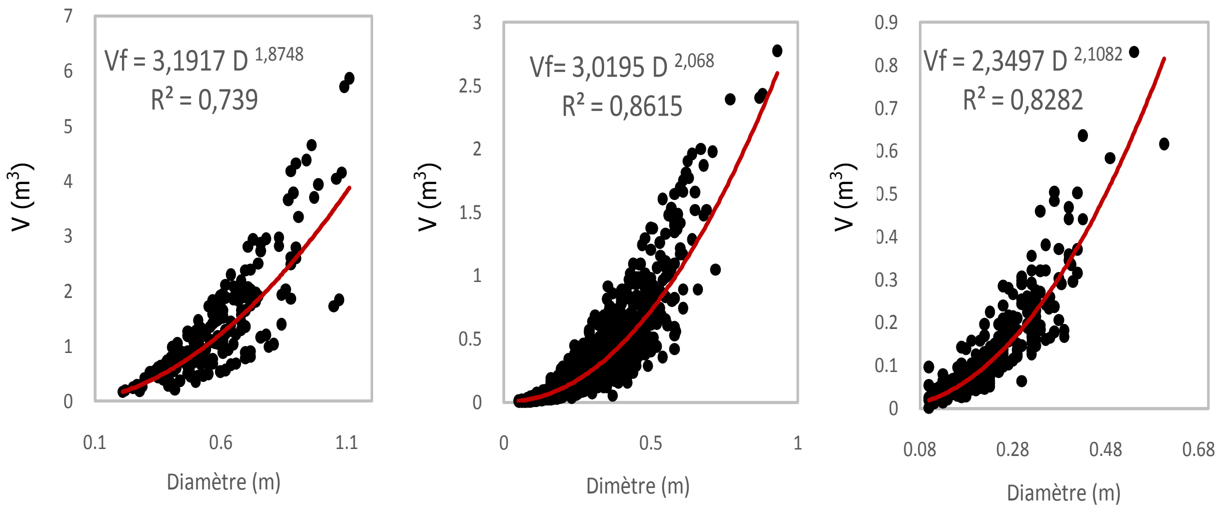
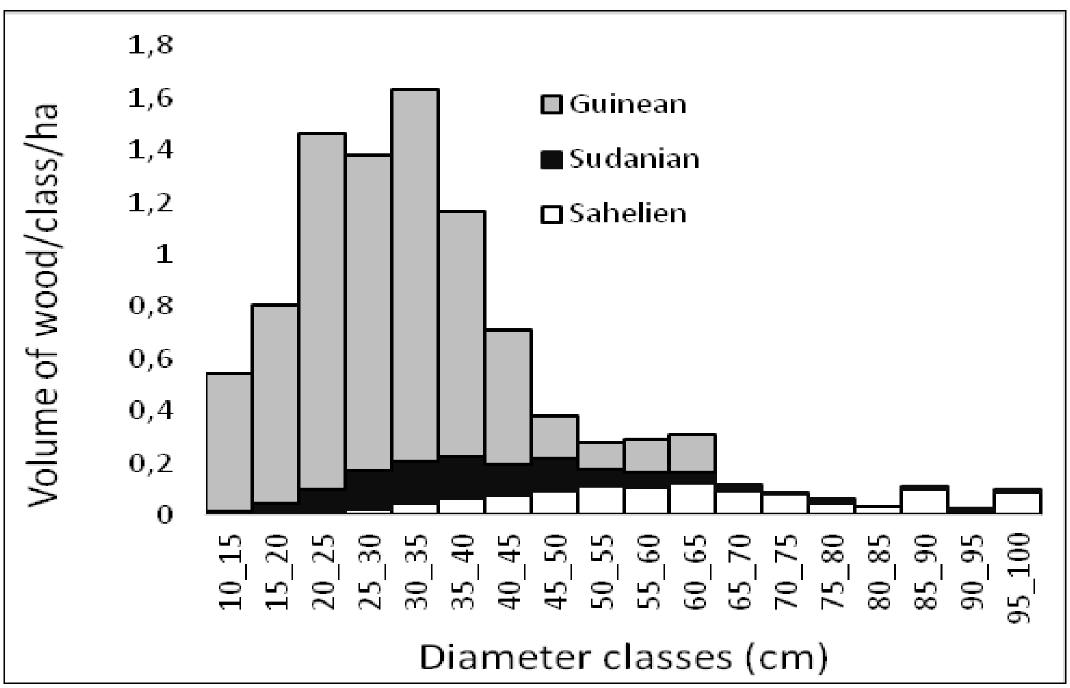
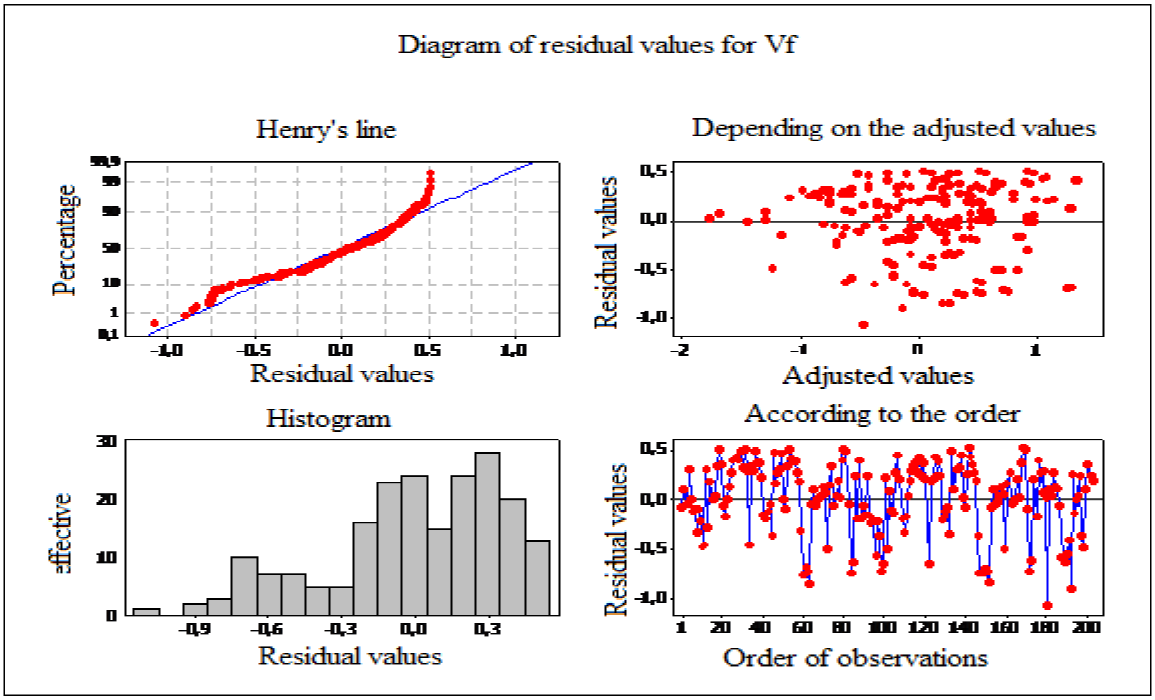


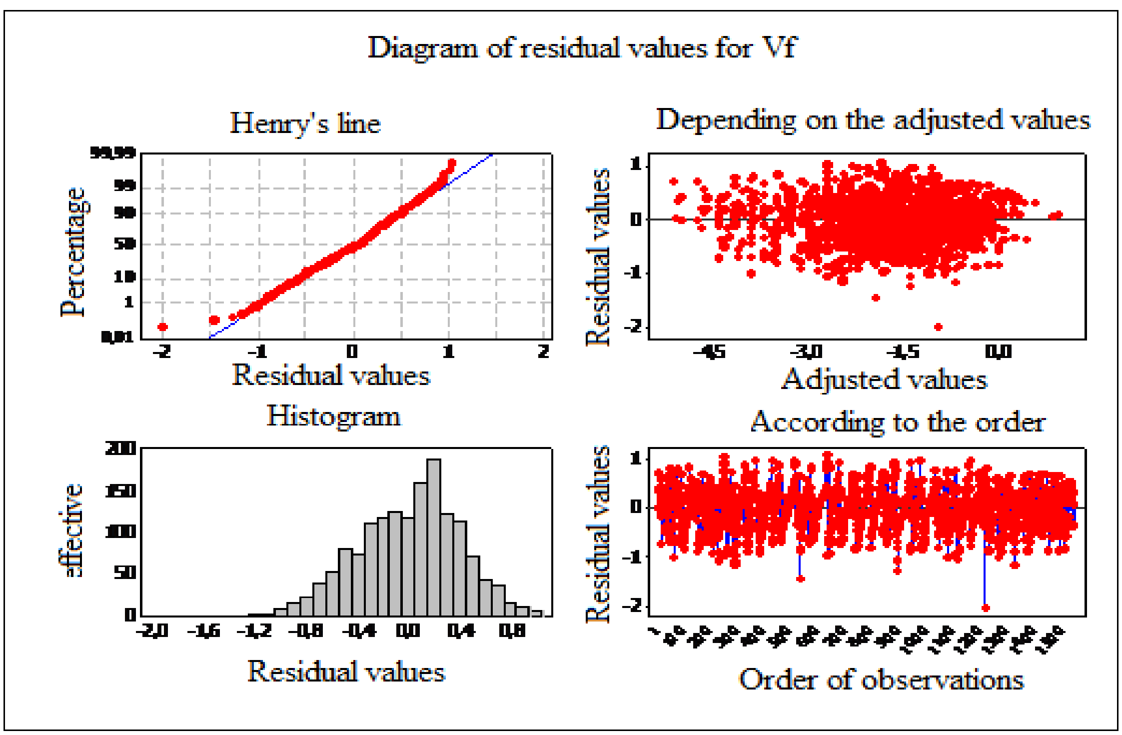
Figure.4 Variability of the volume of wood according to diameter classes



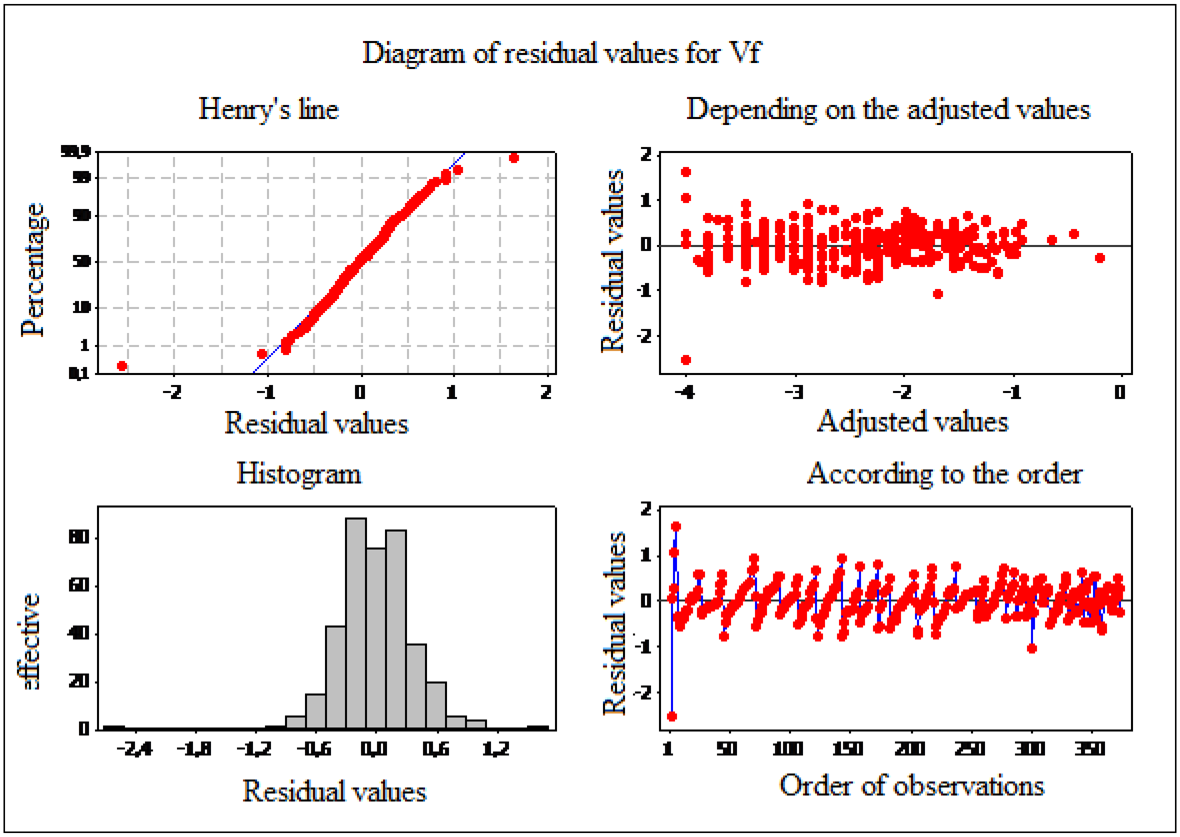
Appendix.1 Diagram of the residuals values for the final volume (Vf)
Sahelian zone



Sudanian zone



Guinean zone



The power model with single entry has already been used in many countries such as Cameroon (Fayolle et al., 2013), Gabon (Bilé, 1999) and the Central African Republic (CTFT, 1964). Other efficient models arealso polynomial or quadratic models (Fayolle et al., 2013) but more complexes in terms of applicability.

Prégent et al., (200), claimed that the single entry volume cubages appear less accurate than the volume cubages with two or three entries although they are more flexible and faster to be used. The shape of the stem and especially the relationship between the diameter at breast height (DBH) and the total height can vary depending on the age of the tree, making the volume cubages with single entry more restrictive (Pardé et Bouchon, 1988).

Therefore, based on the selected power model qualified for each of the three climate zones, the quantification of the merchantable volume indicated that of the three zones considered, the Guinean zone has a higher wood potential than the other two zones. This is explained by the high density of trees observed in this zone.

However, the similarity between the wood volume encountered in the Sahelian and in the Sudanian zone is explained by the fact that in the Sudanian zone, despite a high density (Table 3), the proportion of small diameter trees is important. The predominance of young individuals observed may reflect the selective cutting of *P. erinaceus* trees in this zone. Kokou et al. (2009) and Adjonou et al., (2010) showed that the species is extremely exploited for timber and service timber in the GS zone. It is also widely used as first class energy wood (Fontodji et al., 2011; Fontodji et al., 2009; Kokou et al., 2009; Fontodji, 2007).

This study allowed the development of volume cubage specific to *P. erinaceus* in GSS zone in order to provide it with a good commercial value. Results indicate that the total number of trees sampled is largely enough (2114 trees) to obtain best qualities models. Of all the models with single entry tested (linear, power, quadratic, polynomial models) and by taking into account all the statistical tests and the selected criteria of the best model, the "power" models appear as the most adapted to the Guinean, Sudanian and Sahelian zones. The corresponding equations for each zone are expressed as follows: $Vf = 3.1917\ D^{1,\ 8748}$ (Sahelian zone),$Vf= 3.0195\ D^{2,\ 068}$ (Sudanese zone) and $Vf = 2.3497\ D^{2,1082}$ (Guinean zone). Based on the power model, the quantification of the merchantable volume shows that the Guinean zone has a higher wood potential than the other two zones. These findings constitute an important basis for the management and sustainable use of *P. erinaceus* stands in West Africa. They provide the basic tools for the indirect estimation of the species volume in the GSS zone. Finally, they also allow the classification of the stands into productivity or fertility categories; making predictions for a given forestry and serving as silviculture standards. Plantations based on *P. erinaceus* may be considered with predictions on the volume to be collected annually.

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