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The study of the population structure and the renewal status of *Xylopia aethiopica* (Dunal) A. Rich, *Annonaceae* in the sudano-guinean zone, Cameroun

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ABSTRACT

Xylopia aethiopica, known as "kimba" in the northern part and "akwi" or "ekwi" in the southern part of Cameroom, is an indigenous plant deeply valorised in Africa. The study aims to assess its population structure and dynamics effect contributing to the sustainability management of the natural resources in the Sudano-guinean zone in Cameroon. The methodological approach was the individual inventory of trees along transects which include the determination of their dendrologous measurements. In the forests, 445 trees of *Xylopia aethiopica* were counted. The average diameter at breast high (dbh) varied from 15 cm to 34 cm and the average diameter of the felled trees was 45 m indicating that mature trees were systematically felled. The height of trees varies from 15.42 m (Pangar) to 29.35 m (Mbitom), this great height constrained the harvesters to use the whole felled tree method to collect the fruits. The rate of renewal was very low. The mode of exploitation was not sustainable. The

market demand increased whereas the resource becomes scarce. The recommendations were made for a sustainability of the resources. The domestication of the plant appears salutary permitting the populations to continue benefiting.

Key words: *Xylopia aethiopica*, fruits, regeneration, sustainability, forest, Mbitom-Pangar.

INTRODUCTION

In the sub-Saharan Africa, a tree plays an essential role in the life of the rural population. It provides essential foodstuffs, drugs, fodders, and wood-energy. It and occurs in the maintenance and stability of the ecosystems (Akpo, 1998; Gning, 2008; Mbow, 2008; Bakhoum *et al*., 2011b; Ngom, 2013; Sarr *et al*., 2013 a). *Xylopia aethiopica* (Dunal) A. Rich, *Annonaceae botanical family,* is a multi-purpose specie which grows predominantly in humid forest zones of West Africa (Le Thomas, 1969; Puri and Talata 1978). It is a well-known tree of the local populations of which its fruits and seeds are strongly used as spices and is mostly known as "African guinea pepper" or "Ethiopian pepper" with its straight stem and smooth bark. It is always green in color with a consistent aroma (Le Thomas, 1969; Berhaut, 1971; Adjanohoun *et al*., 1980). *Xylopia aethiopica* is widely spread in tropical Africa, Zambia, Mozambique and Angola (Nnodim *et al*, 2011). In Nigeria, it is found all over the lowland rain forest and mostly in the fringe forest in the Savanna zones. "Negro pepper" as it is also known, has been used as a pepper substitute in Europe and India (Odebiyi and Sofowora 1978). Various parts of the plant are used in assorted fields. The bark of this plant is useful in the "walls" of the traditional houses. It is also used as a platform in the traditional traps (Brisson, 1988). The wood of *X aehiopica* is used in the reinforcement of the roofs of traditional houses (Dalziel, 1937). In traditional medicine, the decoction of the leaves is used against rheumatism, vomitory, macerated in palm wine (Le Thomas, 1969). It is a stimulant and tonic remedy. *Xylopia aethiopica* is one of the medicinal plants which are of high medicinal value in many African countries (Burkhills, 1985). In Senegal, the decoction of the fruits is advised to new mothers as reconstitution baby (Berhaut, 1971). On the other hand, it is prescribed in Ghana to facilitate delivery (Burkill, 1985). In Niger, the mixture of the fruits of *X aethiopica* to the leaves of *Solanum nigrum* has a haemostatic effect on wounds (Adjanohoun *et al.*, 1980). The essential oil of xylopia is active on the insects, the germs and parasites (Tatsadjieu *et al.*, 2003; Kouniki *et al.*, 2005; Fekam, 2004). It also treats bronchitis and the dysentery. The aromatic roots and fruits of the plant are used to stop bleeding, probably due to its antiseptic properties; the aqueous concoction is usually

administered after child birth (Burkhills, 1985; Okeke *et al*., 2008). Many diterpenes were isolated in the fruit and bark of the plant, as the acid xylopic and the annonaceine, an alkaloid resembling morphine (Burkill, 1985). The seeds and fruits have a scented and peppered flavor and are good spices, substitute of pepper (Berhaut, 1971; Adjanohoun *et al.*, 1980). *Xylopia aethiopica* is since a long time exploited for its fruits in several localities of the sudano-guinean zone of Cameroon. The needs and the uses of the fruits cross the borders of the exploitation zone. The fruits are sold in the markets of the northern part of Cameroon and others. The market demand is increasingly significant and has as a corollary increase in the exploitation of the specie in its area growth. Unfortunately the resource because infrequent of an intensive exploitation. The mode, the strategies of harvesting and the overexploitation of this plant represent a significant ecological constraint. It is to be feared that it should not disappear from the natural ecosystems of production.The aim of the study was to contribute to the sustainable management of the multi-purpose species. More specifically to: (1) determine the structure of the population of *Xylopia aethiopica*; (2) assess the impact of the exploitation on the specie population and, (3) evaluate its regeneration status.

Materiel and Methodes

Study area

The study was conducted in the localities of Mbitom and Pangar, where *Xylopia aethiopica* was exploited in some forested areas (Figure 1). These localities were located between the 5° and the 7° N and the 13° and 14° E. In the administrative plan, they belong respectively to the East region in Betaré-Oya subdivision and the Adamaoua region in Ngaoundal subdivision. The climate was the sudano-guinean type with two seasons: a period of eighth months of rainfalls (March to october) and a period four month of dry season (November to February). The annual average rainfall was between 1800 mm and 2200 mm annually with an average temperature of 31°C. The vegetation was characterized by the contiguous savanna forest. The vegetation cover was represented by 10 % of its equatorial forest primary having species with great exploitable trunks like timber. Certain species were subjected to an illegal and anarchistic overexploitation by the local populations. Agriculture and hunting constituted the principal activity of the population, with majority represented by

Gbaya.

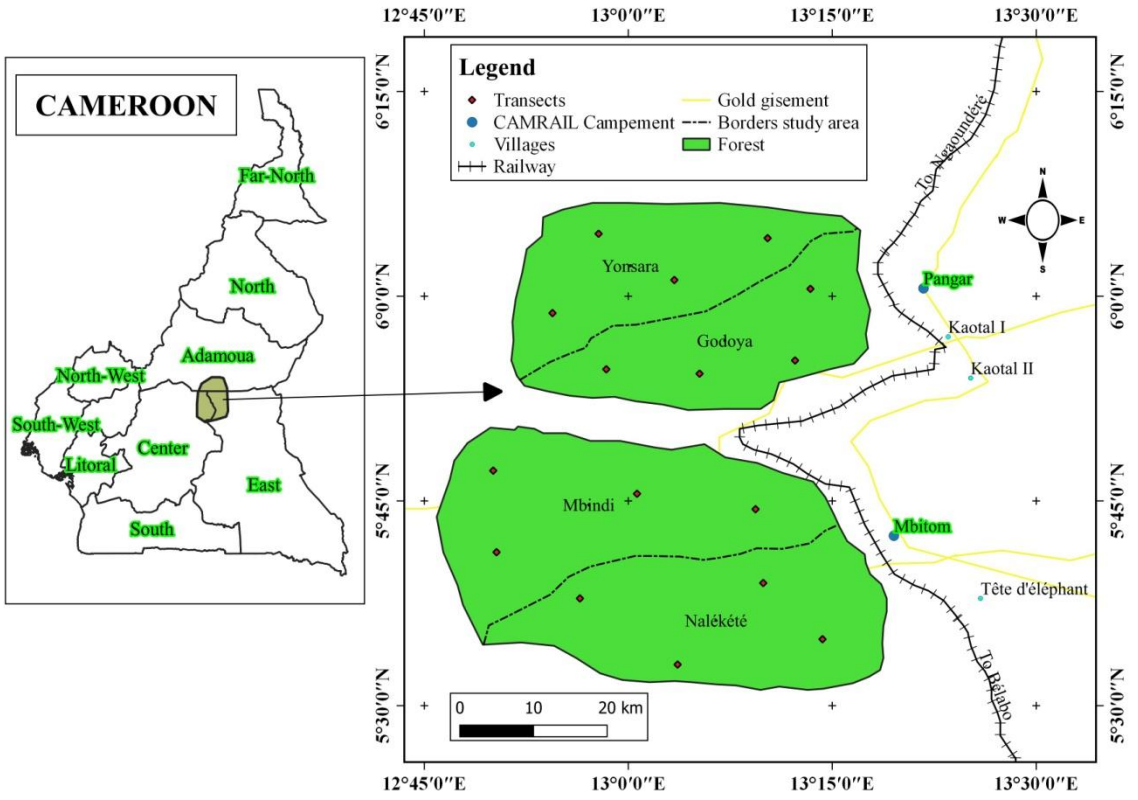


Figure 1 : Study area and the transects itinerary in the forests.

Data collection

To carry out this study, four (4) forested areas situated in two localities, in which *Xylopia aethiopica* was exploited, have been chosen according to the criteria's of the activities of exploitation in Mbitom (Mbindi and Nalekete) and in Pangar (Yonsara and Godoya). The ages of Xylopia exploitation was different in each forested area as follows: Mbindi (5 years), Nalekete (4 years), Yonsara (12 years), and Godoya (13 years). In the whole, 16 transects of 2000 m length and 10 m width were established in the four forested areas, laid out randomly following various orientations. The exploited device was of the mono tree type. The dendrometric data were collected on *Xylopia aethiopica* trees along transects in the forest as the circumference (≥10 cm) of all trees was measured at breast height 1.3 m from the ground, using a decameter. The height and the diameter of the tree archway size were estimated and measured. All anthropogenic traces were observed and noted on each tree. Inside transects, plots of 20 m x 20 m was carried out in a random way to count the seedlings individuals of the plant. Thus, the numbers of seedlings and that of

rejections on the stumps of the felled trees were counted. The stumps of the felling trees and the dead trees or stumps were also counted and their height were measured.

Data analysis

The dendrometric parameters in particular the diameter of the tree, basal area (G) and the density of *Xylopia aethiopica* were calculated. The basal area (G) was the sum of the surface of the cross sections of the individuals measured at 1.30 m on the ground. It was determined by the formula: $G = \sum_{i=1}^{n} C_i^2 / 4\pi$ with G, basal area of the trees at transect and Ci, for the circumference. The density was the number of trees of *Xylopia aethiopica* counted per hectare. The regeneration rate and the death rate of the population of *Xylopia aethiopica* were calculated and expressed as a percentage. For the structure in diameter of the population, measured, individuals divided in classes of diameter 20 cm of amplitude for diametric distribution, height distribution, tree archway size in class height and class size of amplitude 5 m. This distribution was translated by histograms by Microsoft Excel. The other aspects, such as the calculation of average, their comparison, the percentages and ANOVA were done using test statistical by XLStat 9.5.

Results and Discussion

Dendrometric characteristics and density of *Xylopia aethiopica*

The diameter at breath height (DBH) of *Xylopia aethiopica* in the sudano-guinean zone was 31.04±14.92 cm in average. The DBH average were noted in the forests and localities as follows: 15.28 ± 10.46 cm in the locality of Pangar with 14.22±8.80 cm in the Godoya forest and 16.34±12.13 cm in the Yonsara forest and 35.11 ± 12.79 cm in Mbitom with 37.32±12.14 cm in the Mbindi forest and 32.89±13.44 cm in Nalekete forest (Table 1). A smallest dbh (14.22 ± 8.80 cm) was obtained in the Godoya forest in the locality of Pangar and the greatest sizes (37.32±12.14 cm) were recorded in the Mbindi forest in the locality of Mbitom. The difference in the age of the exploitation activities in the two localities significantly influenced the average diameter of trunk of *X. aethiopica* in the various forests of exploitation (P = 0,030). There was a high significant correlation between Mbindi and Nalékété (p = 0.002) and Yonsara and Godoya (p = 0.045).

In the sudano-guinean zone, *Xylopia aethiopica* was covered with its basal area 9.62 m^2 ha^{-1} of land. In the various forested area it was varied from 1.33 m^2 ha^{-1} in Yonsara to 3.47 m^2 ha^{-1} in Nalekete. The individuals of *X. Aethiopica* covered 3.12 m^2 ha in the Mbindi forest

and 1.70 m^2 ha^{-1} in the Godoya forest. There was no difference between the basal areas of *X. Aethiopica* in the four explored forests. The weakness of the basal area of *X. Aethiopica* showed that numerous individuals of this plant were felled. The activity of exploitation by felling down trees which was concentrated on large trees contributed to the decrease the number of individuals especially on their sizes.

In the various forests, *Xylopia aethiopica* was characterized by 26.039±9.33 m height in average. The height was respectively 15.42±4.55 m and 29.358±7 m in Pangar and Mbitom. The highest trees were identified in the forest with 30.01 ± 5.85 m height. On the other hand in the forest of Pangar, trees were small in size with a height of 12.07 ± 5.09 m (Yonsara) and 18.78 ± 4.03 m (Godoya). The number of individuals counted in the forest of Pangar in a general way was low in height.

The average of tree archway size varied from 3.78 ± 3.19 m in Pangar to 11.07 ± 5.144 m in Mbitom. The smallest tree archway size was noted in the forests of Pangar with 3.78 ± 3.19 m (Yonsara) and 6.13±3.16 m (Godoya). The individuals developed a large archway size in Mbitom with the average values of 8.68 ± 4.68 m (Nalekété) with 11.07 ± 5.144 m (Mbindi). The diameter of tree archway size was low (7.40 m) in the forest of Pangar. Results suggested that *X aethiopica* develops a small archway size. But taking into account the difference between the duration of the exploitation in the two localities, results showed that in Pangar, the large trees were felled down. The relative great size of diameters and height observed in Mbitom were explained by the fact that the exploitation of the species was most recent.

In the forests of Mbitom and Pangar, a total of 445 individuals of *Xylopia aethiopica* were counted giving a density of 13.79 individuals' ha^{-1}. This density showed that, *X aethiopica* was not common specie in MBitom and Pangar forests. A similar conclusion was formulated by Sunderland et *al.* (1998) at the inventory of *Pausynistalia johimbe* in the forests of Cameroon and Equatorial Guinea, in which they noted that a density of 15 stems ha^{-1} did not confirm the assumption that species were common. In the same way, this result was higher than those obtained by Peters (1997), within the framework of the inventory in Brazilian Amazonia and in the reserve of Pasoh, which showed that the density of the individuals was of two individuals per hectare.

Table 1. Density and dendrometric parameters of *X aethiopica* in Mbitom and Pangar forests.

Locality	Forest	Number of individuals	Basal area (m^2 ha^{-1})	Diameter (m)	Height (m)	Tree archway size (m)
Mbitom	Mbindi	176	3.47	37.32±12.14	30.01±5.85	11.07±5.14
	Nalékété	164	3.12	32.89±13.44	28.69±8.15	8.68±4.68
	Yonsara	70	1.70	16.34±12.13	12.07±5.09	3.78±3.19
Pangar	Godoya	36	1.33	14.22±8.80	18.78±4.03	6.13±3.17

Structure of the population of *Xylopia aethiopica*

Diametric structure

The structure distribution of *Xylopia aethiopica* stems was distinctively variable in each forest. The maximum individuals was concentrated in the section of diameter ranging between]10-20] cm for the old exploited sites (Godoya and Yonsara) and between 30 and 40 cm for the new exploited sites (Mbindi and Nalékété). This result suggests that, in these forests, the grown-up trees out of fruits and of which the diameter higher than 30 m were systematically felled down. This tendency was illustrated perfectly by the curve of distribution of trees along transects in the older exploited forests. In the new exploited forest, the curve took a more or less normal form in the shape of bell. Sunderland *et al.* (2003) described a contrary behavior on the harvest of the non timber forest products in the Takamanda forest reserve.

The population distribution of *X. aethiopica* showed two categories of behavior. In the first type of behavior, the distribution of the species in the forest of Mbitom had a pace out of bell (Figure 2 a). The mature individuals were most numerous while the old trees of the large diameter and the young people of lower diameter were scarce. This tendency was in conformity with that of a forest. The seedlings were heliophilous consequently the regeneration of a species was only possible in the favor of perforated canopies. Moreover, the exploitation of the plant had just started, it was just for the period of 5 years; the adult trees still exist. In the forest of Mbindi and Nalékété, the greatest number of individuals was observed in the diameter sizes from 30 to 50 cm.

In the second behavior, the distribution of individuals took a particular form, introducing a total failure of the young individuals with a diameter lower than 10 cm and 30 cm for the higher individuals in diameter. The adult trees with large diameter completely disappeared in the Godoya and Yonsara forest; in which the exploitation of the plant dated (12 or 13 years) (Figure 2 b). In these exploitation sites, the most significant number of

individuals was counted in the sizes from 10 to 20 cm. These results showed that in these forests, the individuals of *Xylopia aethiopica* counted in these sizes of diameter were either of the nonproductive trees or of trees which archway size were less importance. These did not permit to harvest a significant quantity of fruits. In addition the plant did not develop a large diameter; adult individuals had a dbh ranging between 10 and 70 cm. The same observations had been made by Le Thomas (1969) at the time of the inventory of the flora of Gabon. According to this author, the dbh of *X aethiopica* varied from 15 cm to 75 cm.

In a general way, the distribution of the stems of *Xylopia aethiopica* in the diameter classes, however showed a weak representation of the individuals in the classes less than or equal to 10 cm and an absence of stems in the greater classes of more than]40-50] cm diameter, in spite of its more or less normal form according to the various studied forests. These results showed that the exploitation was selective, and related to the adult trees of which their summit were larger, having consequently a significant potential in fruit-bearing production. The threat weighs on the species and more in this category of individuals, because the producing adult trees in fruit-bearing biomass were exploited and the development of the seedlings was very slow and / or difficult in under wood.

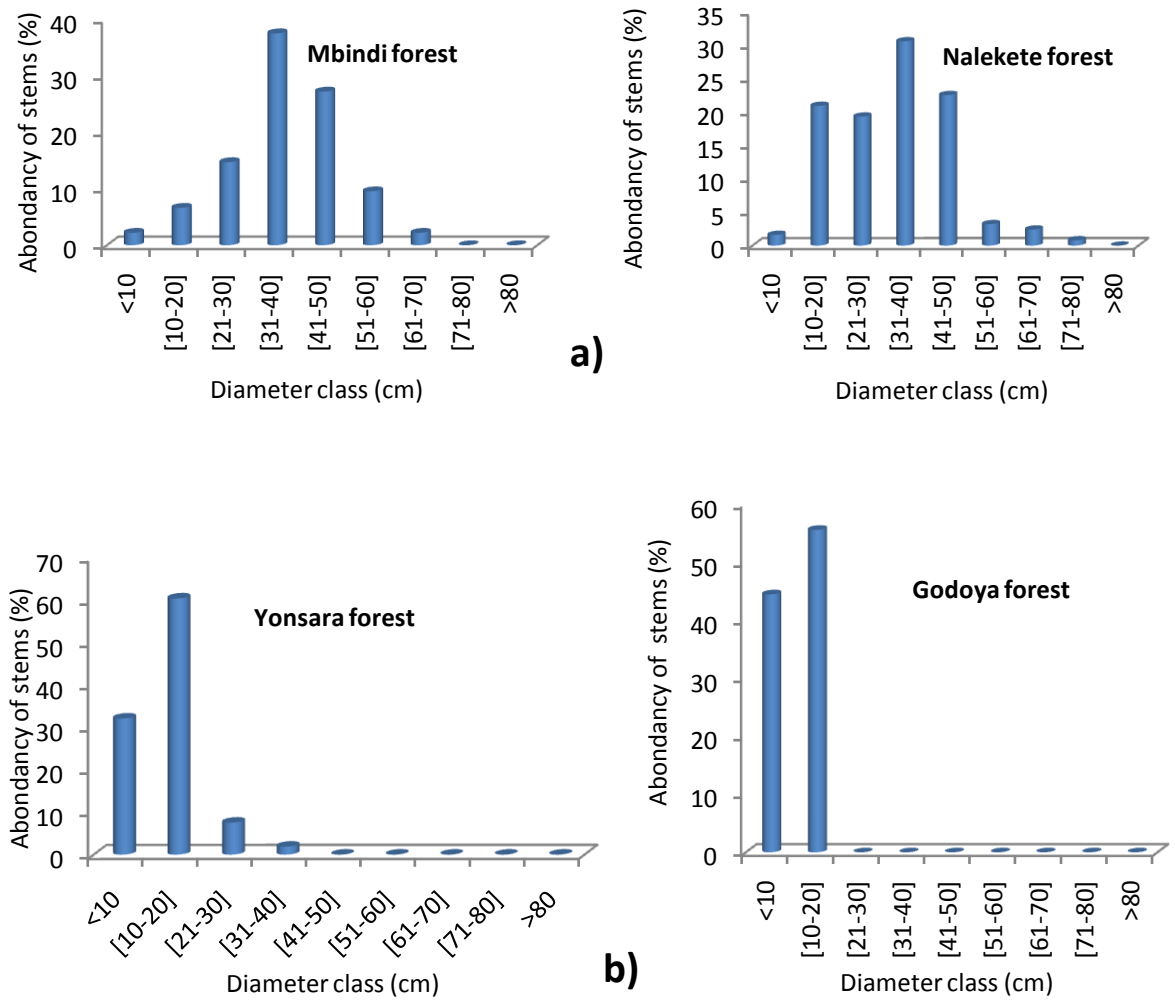
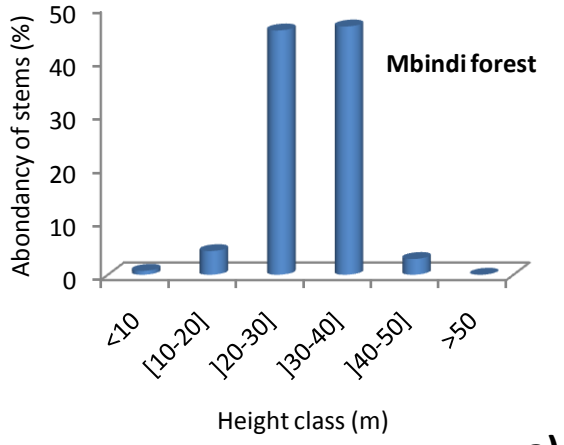


Figure 2. Distribution of individuals of *X. aethiopica* according to diameter size: Mbitom (a) and Pangar (b).

Height structure

The average height of the tree was 29.35 m in Mbitom and 15.42 m in Pangar. The maximum rate of individuals was concentrated in the section height ranging between]20-30],]30-40] m in Mbitom with many individuals in the forest of Mbindi (91.90 %) and Nalékété (74.5 %). In the forest of Pangar (Yonsara, 62.26 % and Godoya, 52.63 %) the individuals belong to the class from]10-20] m. Comparatively with the forest of Mbitom, the individuals were fewer and low in height. In a general way, *X aethiopica* was a species of very great height. The height of this species constituted a significant constraint for farmers to easily harvest fruits, thus justifying the choice of systematically felling down trees for the

harvesting of fruits process. The distribution of the trees according to the height parameter follows a more or less normal tendency (Figure 3). This distribution tends to follow the distribution of individuals in diameter classes in the forests. This tendency confirmed the scarcity of young individuals and that of the adult individuals correlated to the too low renewal status of *Xylopia aethiopica*. The majority of adult individuals were felled. There remain only the young individuals which were not productive and which were likely to be exploited in future. If nothing is done to stop the exploitation activities and the regeneration of this specie, it will disappear in the forest.



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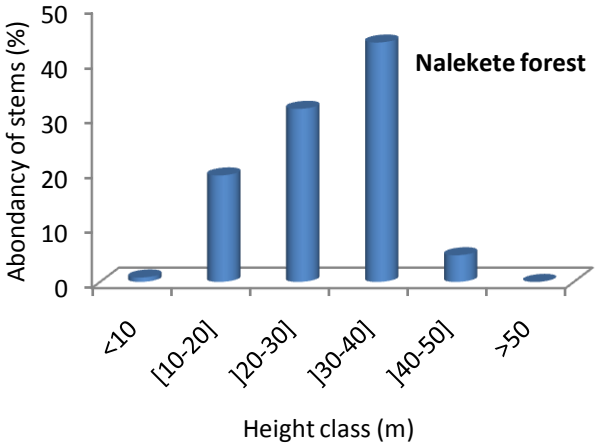


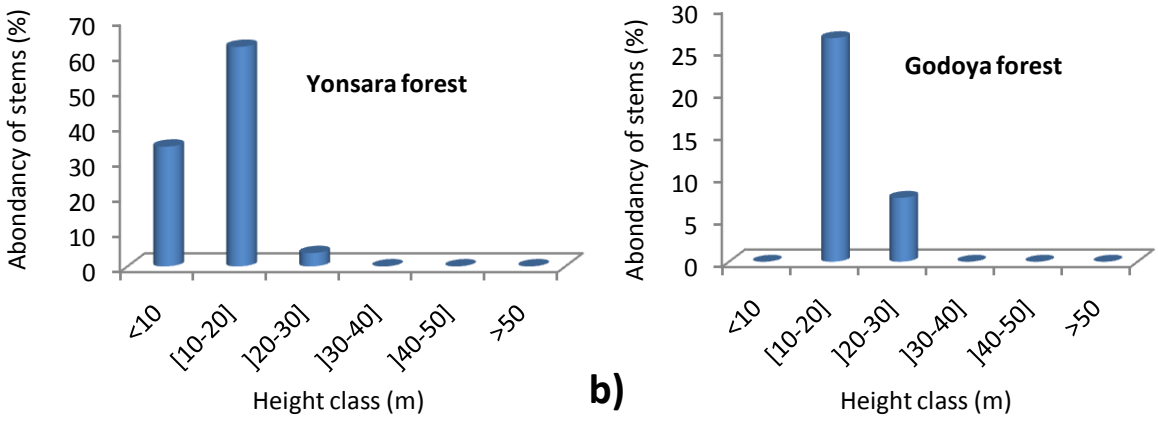


Figure 3. Distribution of individuals in height classes in the various forests: Mbitom (a) et Pangar (b).

Mode of exploitation and impact on the resource

Xylopia aethiopica was exploited by the whole felling down trees with fruits. This operation of felling constituted for farmers the only alternative, in spite of its harmful effect on the population of the specie. Felling down trees was the only means of harvesting fruits (Figure 4). The process of obtaining the selling fruits continued with the collection, drying with fire on tray and conditioning in bags for flow in the markets. The work of felling down trees was done in group or individually; as far as possible. Farmers settle in the campsite sarong of forest. Only the ripe fruit trees were cut. The criteria used for the choice of trees to cross were between the presence of fresh pulp on the ground under tree or the presence of fruits on the tree. As soon as these conditions were met, they sharpen their material of cutting, felling down trees, prune them and collect the fruits. The drying of fruits constituted a significant stage of the exploitation; it was the treatment of the fruits before conditioning (Figure 4). It was done only on one tray a 120 cm height under which fire was poked. The drying process took 4 to 5 hours per day and when it was not completed, it could be taken again the following day.

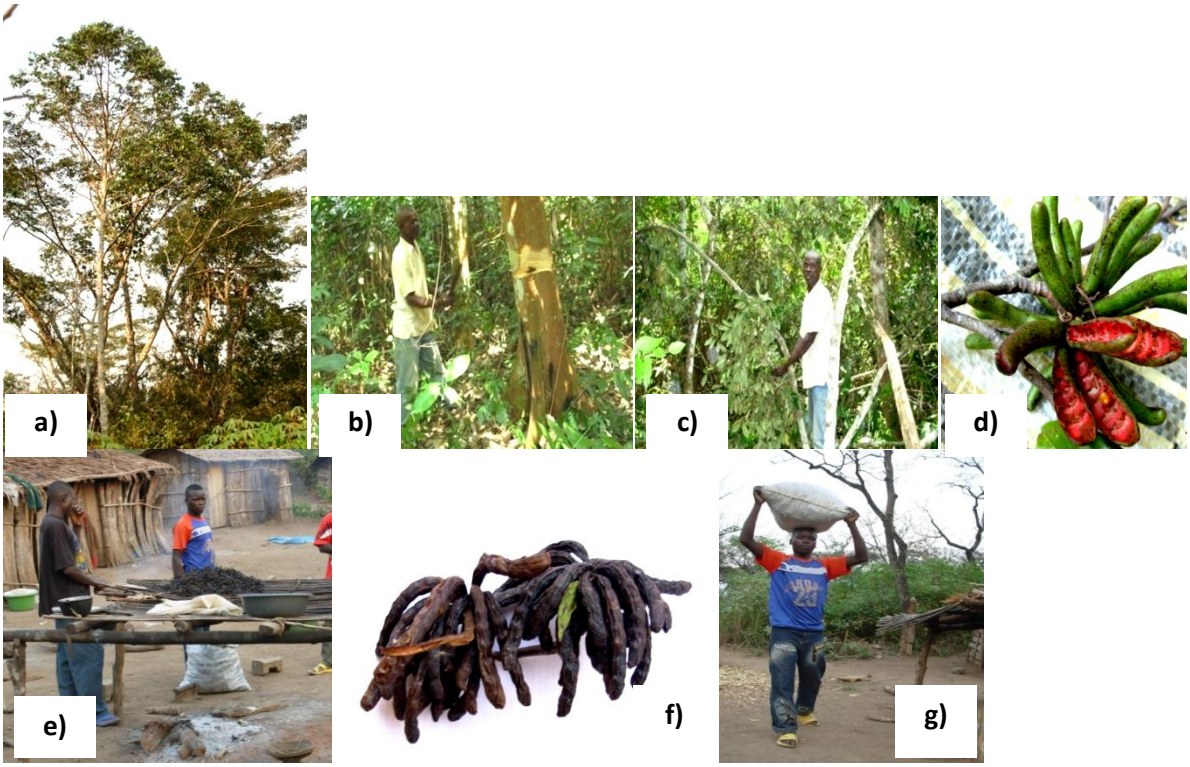
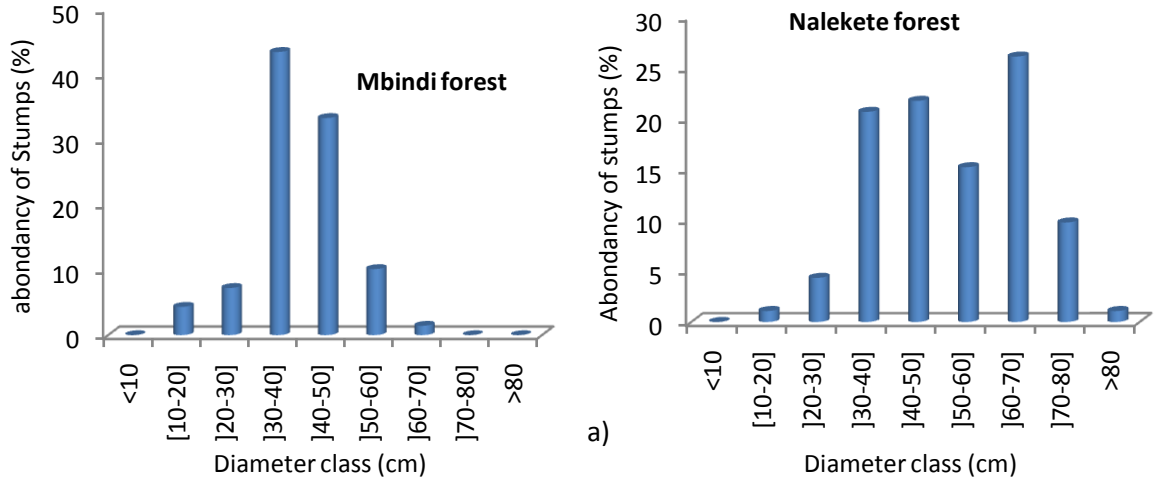


Fig. 4. Activities of exploitation *Xylopia aethiopica* (A), felling trees (b), collection of fruits (c), ripe fruits (d), drying process (E), fruits dried (F), conditioning of fruits (d).

Impact of the exploitation on *Xylopia aethiopica* populations

In the various explored forests, it was counted 228 stumps of *X. aethiopica* representing the number of felled down stems, as a density of 7.12 stumps per hectare. These stumps recognizable were ranging between 1 and 5 months as from the date of felling down tree. Beyond this time, some stumps perished. These results showed that, the exploitation of the specie was intense in these forests. The average diameter of the stumps was equal to or higher than 40 cm in the various forests, showing that the cut individuals were in majority on large trees. The distribution of stumps in the forests (Mbitom and Pangar) according to the diameter presented a bell shape (Figure 5). This tendency was due to the fact that young trees did not produce fruits yet and were not needed by the farmers. The old trees were already felled down on the first years of exploitation. However, the previous analysis showed through the distribution of the population those adult individuals were more numerous; the exploitation activity was currently concentrated on this category of individuals. The most significant number of stumps were found in the diameter classes of]30-40] to]40-50] cm with a variable number of individuals in one forest to other: Mbitom (76,80 %) and Pangar

(60 %). A particular mention was noted in the forest of Nalékété in which a high proportion of individuals (26.08 %) was in]60-70] cm class. The difference in proportions observed between the forests would be related to the number of farmers and the age of the exploitation. The forest of Pangar has been in exploitation for 13 years and the large stem became rare. The exploitation took place only by the whole felling down trees of *X. aethiopica*. The rate of felling down trees was rather significant, and constituted a factor of extinction of the specie. The process of the tree was not sustainable; it instead contributed to the extinction of the specie and the transformation of the aspect of the forest following the fall of trees which caused openings and the destabilization of the forest ecosystems.



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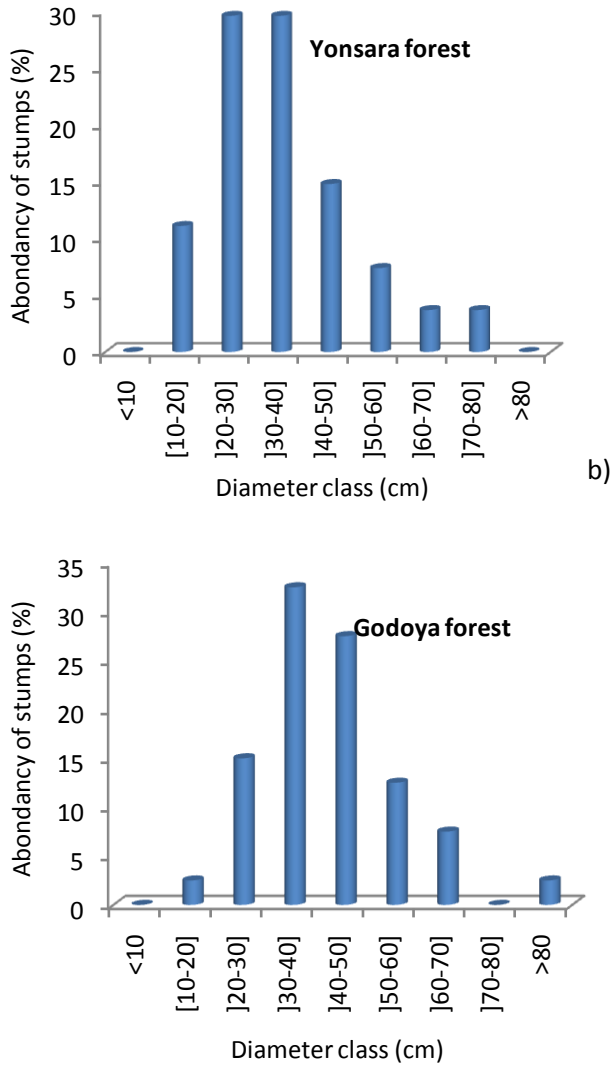

Figure 5. Distribution of stumps in the various forests: (A) Mbitom, (b) Pangar.

Capacity of regeneration of the specie

After the felling of trees, some stumps located in open area under the canopy could remain alive and emitted rejections. The mortality of the stumps was very high in the different forests: 98 % in Nalékété; 95 % in Godoya; 92.75 % in Mbindi and 77.77 % in Yonsara. The strong mortality of *X. aethiopica* stumps in the various forests would be related to:

- the period of the felling which intervened during the raining season. Significant quantities of precipitations could be the causes of the death of stumps;

- the position of the stump in Underwood or its exposure to the light. The quantity of light was weak and did not allow the physiological released of buds;

- the level of the cut or the height of the stump could also play a role. In the fields, stumps having emitted rejections belong to varied diameter classes. The rejections were observed all along the stumps and were based up to the height of the felled trees.

In the forests of Mbitom and Pangar, only 13 stumps emitted rejections. The number of rejections by stumps of *Xylopia aethiopica* varied according to the type of forests. The rate of reiteration varied from 5% in Godoya to 22.22 % in Yonsara (Figure 6). These results showed that the plant could emit rejection on stump after the felling.

In the forest, a number of 57 rejections were counted on the stumps, but the survival of these rejections remained hypothetical. In the natural conditions, the stumps emitted an average of 4 rejections per stump. Much more in the places of the forest where a canopy was closed, no stump survived. The majority of the living stumps were met in the skirt of the forest where the incidental light was significant. These various behaviors suggest that light was a factor determining the regeneration of the specie.

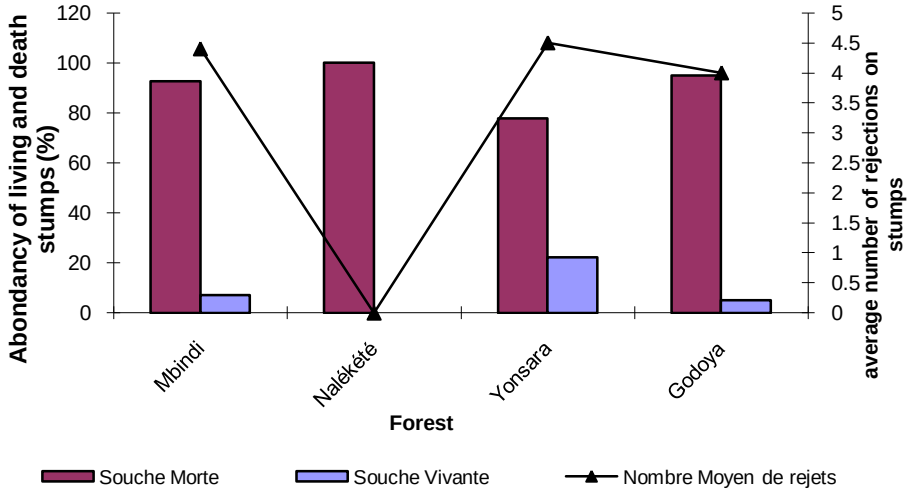

Figure 5. Type of stumps and the number of rejections in the various forests.

Regeneration by germination of seeds in the natural conditions was observed starting from the seedlings. In the various forests, a total of 250 seedlings were counted. The number of seedlings varied from one forest to another: Mbitom (163) and Pangar (87). The greatest number of seedling was observed in the forest of Nalékété. The seedlings were seen under trees of *X aethiopica* and other species. In the underwood, the seedlings and the young trees were scarce. The seedlings observed had a majority of height less than 1 m. The quantity of incidental light which crosses canopy was weak and their development was impacted. The presence of seedlings showed that the seeds germinated in nature, and little chance left so that

the plant settled. In under wood, the seedlings were choked and fade by the moisture fluctuations. A similar conclusion was made by Peters (1997) in the tropical forests of Central America and South America. The majority of the seedlings were observed in the openings and constituted the niches of regeneration of the plant.

CONCLUSION

This study permitted to characterize the populations of *Xylopia aethiopica* (Dunal) A. Rich. which was a worthy plant in the transitional zone of the savanna forest in the sudano-guinean aera. It showed that *the Xylopia aethiopica* was not a common specie in the Mbitom and Pangar forest with a low density. The population distribution of *X. aethiopica* was showed that individuals of diameter ranging between 20 cm and 40 cm were most numerous while the individuals whose diameter was higher than 50 cm and the young stems with a diameter less than 20 cm were sparse. The analysis of the state of the populations of this species revealed that these last ones are unstable, with a very weak regeneration in the forest. The average height of the tree was 26.03 m this great height, constrained the harvesters to use the felling down trees process to collect the fruits. The activities of exploitation were intense and contributed to the extinction of the population of *Xylopia aethiopica*. The plant emitted with difficulty rejections after the felling down trees, resulted to the high rate of stumps death. Regeneration by seeds germination was weak; of which the seedlings survive with difficulty until the following season. Taking into account all its difficulties and constraints of exploitation, the domestication of the plant remained an alternative to make it possible to the owners to continue to benefit from the resource.

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