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Sustainable management and population structure of multipurpose species: the case study of *Sclerocarya birrea* (A. Rich.) in the Sahelian zone of Cameroon

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Key words: Population structure, *Sclerocarya birrea*, land use, agroforestry systems, Sahelian area, Cameroon.

1 ABSTRACT

Indigenous tree species were widely known as multipurpose. The study aims to record the main uses of the *Sclerocarya birrea* (cider tree); understand its management patterns, assess its population dynamics and the influence of the land-use on the species distribution in the Sahelian zone of Cameroon. The study was carried out using ethnobotanical and quantitative ecological methods. The results showed that the species was multipurpose and produced six different products and services like medicine, handicraft, human food, animal feed and firewood. The local communities indicated that this species have become rare. The quantitative inventory supported this view: the species had a low density (25 individuals/ha) and a weak Sized Class Distribution (SCD) with calculated least-squares regression slopes of a_1= -0.029 (Agroforestry systems) and a_2=-0.031 (Sahelian area). The SCD plots showed that the population was essentially young and presented an "L" shape. The agroforestry system contained an important density of adult individual and constituted an ideal area for conservation. The species appeared to be overexploited and poorly conserved. Respondents claimed that they were not encouraged to conserve it because the propagation materials lacked. The sensitization and the domestication of the plant should be considered urgently.

2 INTRODUCTION

In Africa, spontaneous fruit trees are known as food, medicine and cash source for households (Haq *et al.*, 2008; Arbonnier, 2009; Bowe and Haq, 2010). Unfortunately, the demographic explosion is one of the problems that have caused the biodiversity loss (Bitariho *et al.*, 2006) and leads to the reduction of the productive potential of the ecosystem (Birkett and Stevens-Wood, 2005). This is likely to reduce the services that are provided by productive ecosystems to local communities. Because of the rising prices of commodities, local communities fall back to the multipurpose species or non-timber forest products to resolve their problems; these NTFPs fulfil different roles in their sustenance, and allow them to live with less cash (Vedeld *et al.*, 2007). In other hand, they play a very important role in the conservation of water, soils and biodiversity by their agroecological functions (Agbogan *et al.*, 2015). In Cameroon, ethonobotanic data showed the important contribution of plant species like *Sclerocarya birrea* in the well being improvement of

the local communities, in particular the one of the Sahelian region (Noubissie-Tchiagam *et al.*, 2011). Unfortunately, most of these plant species disappeared because of the highest pressure practiced by the local communities (Koulibaly *et al.*, 2006; Todou *et al.*, 2017). For this reason, it is important to assess the conservation status of the resource in relation to these impacts to know how sustainable it will be through time. Many authors reported that plant species level research that comprises inventories, impact studies and monitoring is necessary if plant resources are to be harvested sustainable by local communities (Ndangalasia *et al.*, 2007; Gouwakinnou *et al.*, 2009). The ecological parameters, which may guide sustainable management of any given species, are phenology, uses and types of resources produced, abundance in different forest types, and distribution of populations (Peters, 1996). These parameters can be used to understand important demographic stages or ecological variables that merit special focus when implementing a management scheme (Bruna and Ribeiro, 2005). Unfortunately, the empiric data supporting this opinion were limited in Cameroon. Since the last decades, some studies were conducted on the multipurpose species (Sunderland and Ndoye, 2004, Noubissi-Tchiagam *et al.*, 2011). This survey was undertaken to fill this gap through the indigenous knowledge of the species and its population structure in the Sahelian zone of Cameroon. The aims of the paper were to record the main uses of the *Sclerocarya birrea* understand its traditional management patterns and assess its population dynamics and the influence of the land-use type on the species distribution in the context of the Sahelian zone of Cameroon.

3 MATERIALS AND METHODS

3.1 Study area: This work was conducted in the Sahelian region of Cameroon. It is between the 10th and 12th degree of North Latitude (Figure 1). The relief is composed of plains leaned against the Mandara mountains, a massif at the border with Nigeria. The average altitude is 1000 m in mountains and about 300 m in plains (Yengue and Callot, 2002). The climate is a Sahelian type. Annual precipitation is 867 mm on average. The mean annual temperature is 27°C with a maximum of 38 °C from March to April and a minimum of 18 °C from December to January (Suchel, 1987). Its vegetation is dominated by the thorny steppes Sahel. The presence of plants such as *Anogeissus leocarpus* on loose and uncleared soil, *Boswellia dalzieli* on stony soil and *Balanites aegyptiaca* is most noted (Boutrais, 1984). The main activities are agriculture and animals husbandry.

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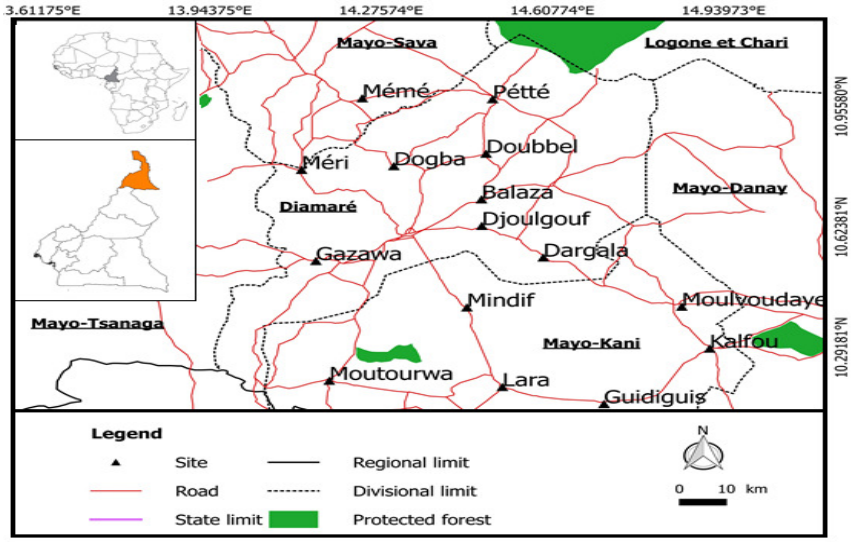

Figure 1: Localization of study site

3.2 Sampling and data collection : The study was carried out using both some ethnobotanical and ecological studies. The ethnobotanical investigations entailed structured interviews were conducted using questionnaires and were administered face to face. At all, 250 persons were interviewed. The interviewed people were 35 to 60 years old and had a good knowledge of local plant species. The questions asked concerned the habitat of the species, the patterns of harvest, the different uses of the species and the attitude of the local community towards its conservation. For the ecological part, three farmers were chosen in each of 15 villages and their farms were visited for field measurements. The entire farm of a given sampled farmer was considered as a plot and its area was calculated for tree density estimation. A total of forty-five plots were established in agroforestry systems. In the Sahelian area, twenty-five 0.2 ha plots were established. In each plot, to avoid possible mistakes of numbering, all individuals of *Sclerocarya birrea* were marked. Presence and abundance of *S. birrea* saplings were also recorded within plots and seedling presence or absence was recorded beneath adult trees. According to Gouwakinnou *et al.* (2009), any plant from germination to basal diameter (at ground level) less than 1 cm were considered as seedlings and plants with stem greater than 1 cm basal diameter or more than 1 m height and less than 5 cm dbh and/or less than 1.5 m height was considered as saplings. The parameters as height and diameter at breast height (dbh) of each of *S. birrea* tree were assessed. Data was also collected on vegetation type and the abundance. Then, all species situated in a radius of 10 m around of *S. birrea* and the number of trees per species was recorded within each plot.

3.3 Data analysis: Shannon Wiener entropy index H and true diversity D (Jost, 2006) was used to characterize each land use type.

$$H = -\sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

$$D = 2^H$$

Where: n_i is the number of trees of species i; n is the overall number of trees inventoried in a considered plot and s is the number of species recorded in the plot.

Pielou evenness index E_q was calculated to measure the entropy degree of the plot compared with the possible maximal entropy Hmax:

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$$E_q = \frac{H}{\log_2 S} \quad (3)$$

Where $\log_2 S$ is the maximal entropy (Hmax).
Using dbh as a measure of tree size, we assessed *S. birrea* population structure and calculated the density per land use type. The Chi-squared tests (Fowler and Cohen, 1988) were used to compare the abundance of species on the land-use types (Agroforestry system, Sahelian area). A size class frequency distribution plot (SCD) was drawn by plotting the number against size class. According to Lykke (1998), the slope of regression and the coefficient of determination were calculated for every sector with regard to the distribution by diameter class. The SCD slope summarizes in a single number, the shape of the SCD (Tabuti and Mugula, 2007). If a population has a strong negative slope, it is interpreted like a stable and naturally able to replace itself whereas the weak negative slopes or the flat slopes show a poor restoration and declining population (Hall and Bawa, 1993; Lykke, 1998). To calculate the slope, the size-class midpoint (d_1) was considered as the independent variable and the number of individuals (N_1) of every class as the dependent variable. To get the straight line, N_1 was transformed in Ln (N_1+1) because some classes have any individuals. The regression was calculated between d_1 and Ln (N_1+1) (Lykke, 1998; Obiri *et al.*, 2002).
We used Green's Index (GI) (Jayaraman, 1999) to appreciate the distribution of the species in each land use type. The index was calculated as follows:

$$GI = \frac{\left(\frac{\sigma^2}{\bar{x}} - 1\right) - 1}{n - 1} \quad (4)$$

Where σ^2 is the variance of the density, $\bar{x}$ is the mean density, and n is the sample size. GI varies between 0 (for random) and 1 (for maximum clumping).

4 RESULTS

4.1 Main uses of Sclerocarya birrea: The different parts of *S. birrea* harvested by the local communities permit to offer various services and products (figure 2). Fifty per cent of the services (Handicraft, human feed and firewood) were cited by 70 % of respondents.

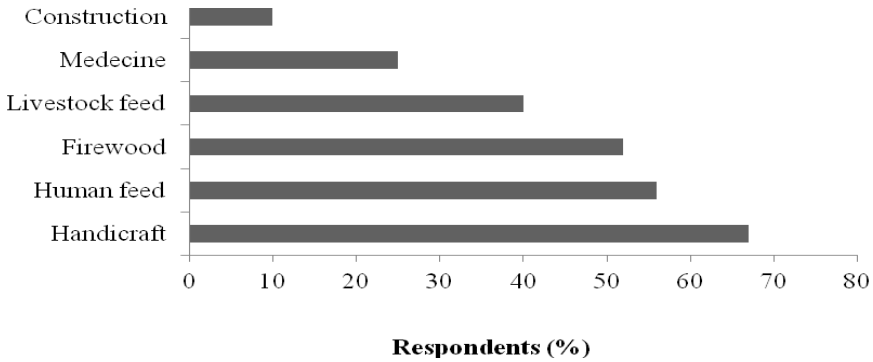

Figure 2: Products and services of *Sclerocarya birrea* in the Sahelian zone of Cameroon

Twenty four per cent of the respondents indicated that *Sclerocarya birrea* was mainly used for the handicraft. The human feed comes in second position with 22.4 % of interviewed people

mentioning this use. The uses relative to the houses construction, the pharmacopoeia and the livestock feed represented 30 %. In the domain of the handicraft, the stem is the part of the tree that is the most solicited. Once harvested, it is used for carve mortars, spoons, plates, sleeve tools. The leaves are browsed by livestock. In the medicinal domain, the local communities used the bark for treatment of tooth decay. For this, when the deducted barks were boiled, the sick bends over the pot and covers itself with a blanket during a few minutes. The powder of the barks is given to livestock for stimulate their appetite. The ripe fruits are sucked and are used for preparing the beverage while the kernels are eaten like the groundnut or are used to extract the oil. Most commonly, the children sucked the ripe fruits when they collected the firewood and ate the kernels after broking the husk with stone.

4.2 Farmer perception on sustainable management of Sclerocarya birrea in Sahelian zone: The management and the conservation of *Sclerocarya birrea* in the survey zone remained a preoccupying subject in famers' environment. Nevertheless, others became aware of the overexploitation, the resource becomes more and more depleted. To support their concerns, some people say that they no longer find *Sclerocarya birrea* individuals in their surroundings or walk several kilometers to meet large individuals. In spite of their desire for a sustainable management, the local communities ignored what strategies to adopt for solve this problem. The presence of the species in the agroforestry systems shows its importance for the local community. The management pattern is variable. It goes from the cut to the selective deduction of the parts (leaves, bark, trunk and fruits) of the plant following the problem to solve. After all, 75 % of the interviewed people did not present a defined program of harvest of *S. birrea*. However, they indicate that they have needed the species all the time. As the pattern of harvest of the plant's parts, the number of deduction per year is variable. The periodicity of the harvest depends on the individuals and the size of the problems met. The bark and the timber are harvested at all the time. The leaves are solicited when the pasture becomes dry. As the exploitation of *S. birrea* is wild, many different opinions on its conservation are expressed. Fifty six per cent (56 %) of the interviewed people thought that the exploitation of the species must stay free whereas sixteen per cent (16 %) of them agree the controlled exploitation of the resource. Those who wished a sustainable exploitation represented thirty one per cent (31 %) of the whole interviewed population.

4.3 Distribution and habitat characteristics: According to farmers, the *S. birrea* individuals occurred both in agroforestry systems and in wild within the study area. About 70 % of farmers hold on farm at least one individual of the species in their farm. In the agroforestry systems, *S. birrea* was associated with others indigenous fruit tree species such as *Parkia biglobosa (*African locust bean), *Balanites aegyptiaca* (desert date or Soapberry tree) and *Tamarindus indica (*Tamarind) and other species such as *Faidherbia albida* (Winter Thorn). In the Sahelian area, the companion species were *Ziziphus mauritiana, Grewia bicolor, Anogeissus leiocarpa, Diospyros mespiliformis*, *Balanites aegyptiaca, Annona senegalensis, Mimosa pigra, Acacia nilotica.* The ecological parameters calculated for both land use types are presented in Table 1. The density of these woody species (dbh>5 cm) was 11.71 stems/ha in agroforestry systems and 115.67 stems/ha in Sahelian area. *S. birrea* was found on all types of soil ranging from less degraded soil to the most degraded ones excepted on the permanent or quasi-permanent flooded areas and on hydromorphic soil. Green's index (GI) used as an index of dispersion showed that the species had a clumped distribution in the Sahelian area (0.56) than in the agroforestry systems (0.06) where the distribution was quasi random.

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Table 1: Ecological parameters of both land use types.

Parameters	Land use	
	Agroforestry system	**Sahelian area**
Shannon entropy index (± SE, bits)	1.69 ± 0.20	1.89 ± 0.33
D (± SE, species)	3.44 ± 1.07	3.89 ± 1.07
Pielou evenness index (± SE)	0.48 ± 0.04	0.48 ± 0.03
Overall species richness	37	42

4.4 Population structure of Sclerocarya birrea: The diameter of the population varied from 5 to 105 cm. Individuals belonging to the diameter class of [5-15[cm were the most abundant (37.4 %). These were followed by those belonging to the diameter class of [15-30[cm (24.3 % of the total population). The adult individuals represented approximately 7.9% of the population of *S. birrea* (Table 2). The juvenile individuals presented different situation according the land use. Its density was higher in the Sahelian area than in the Agroforestry systems. Thirteen per cent of the sampled plots in agroforestry systems contained saplings whereas in the Sahelian area the percentage of sample plots containing saplings was assessed at 45 %. However, the occurrence of seedlings in the two types of land-use did not significantly differ (F=-2.93; P=0.064) but sapling density was significantly higher in the Sahelian area (35 stems/ha) than in the agroforestry systems (3 stem/ha) (F=13.54; P=0.0000). This result was explained by the fact that in the agroforestry systems, the vegetation was cut for agriculture exploitation. When the farmers grew their crops, they preferred that the land could be clean; so they cut all vegetation that could create shade to their crops.

Table 2: Distribution of trees according to the diameter class sizes

Distribution of trees by diameter class (cm)		
Number of trees	**dbh (cm)**	**%**
43	[5-15[	37.4
28	[15-30[	24.3
16	[30-45[	13.9
11	[45-60[	9.6
7	[60-75[	6.1
5	[75-90[	4.4
4	>90	3.5

Despite the fact that the species was presented both in the Sahelian area than in the Agroforestry systems, all the interviewed farmers affirmed that the individuals number of large size were weak or nearly inexistent. They also declared that this species became more and more rare (59 %). The perception of the local communities was confirmed by the analysis of the population structure. The population had weak size class distribution (Agroforestry systems: a_1= -0.012; R_1^2 =0.638; t_1= -4.053; P_1<0.001 and Sahelian area: a_2= -0.029; R_2^2= 0.962; t_2 =-6.780; P_2<0.0001). The plots of size class distribution showed that the population was made up of juveniles and that there was a remarkable absence of adult individuals in the study zone (Figure 3). However, there exist sporadically some adult individuals in the Sahelian area. In the both systems, the population distribution presented an appearance in the "L" shape. Such shape

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suggested that the population of *Sclerocarya birrea* regenerated well in the study zone but that the old individuals are little represented and did not maintain themselves.

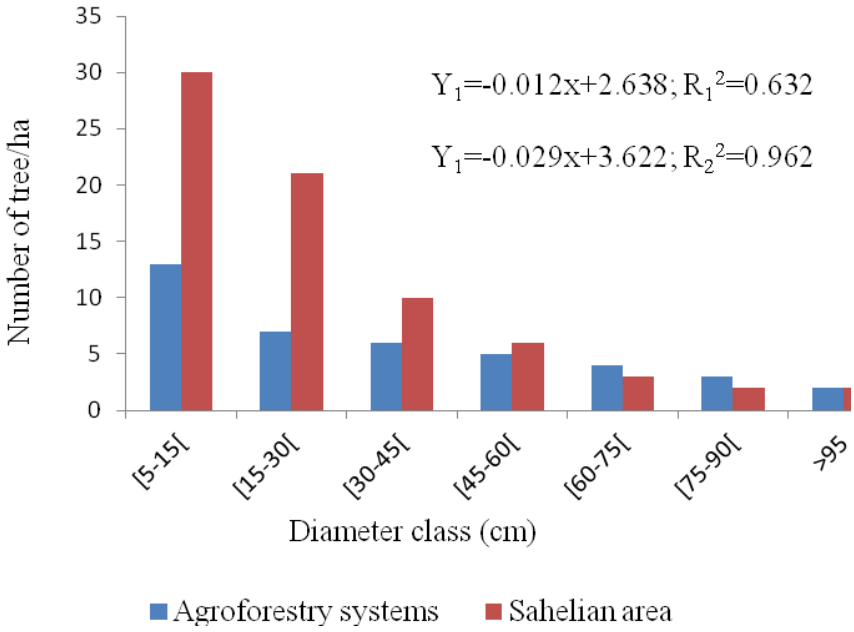

Figure 3: Size class distribution of *Sclerocarya birrea* in Sahelian area and Agroforestry systems

5 DISCUSSION

5.1 Distribution and vegetation: The density of companion species of *S. birrea* in the Sahelian area is about fifteen times higher than in agroforestry systems. This result shows the effect of clearing as the effect of land use on *S. birrea* habitat. Farmers control tree species'densities and presence and hence the diversity on farms, depending on their preferences and species use needs. The trees species that are not used are cut down while the most useful ones are saved. This selective clearing is often done considering the composition of the original tree population, the ecological conditions, the expertise, the requirements of farmers and their socio-economic environment (Okullo and Waithum, 2007). The index of Green used as indicator of the degree of clumping shows that *S. birrea* is more or less clumped in the Sahelian area while it has a random distribution in agroforestry systems. Because of the relatively high mass of the fruit of *S. birrea,* it has, on its own, very limited dispersal ability. Thus, the type of distribution pattern found in the Sahelian area is partly due to dispersal limitation. Moreover, the species has the higher aptitude to reproduce vegetatively from roots (Noubissi-Tchiagam *et al.*, 2011), thus increasing local density could also partly explain the found pattern in the Sahelian area. The quasi-random distribution in agroforestry systems is an indicator of human pressure on the species population in this type of land-use.

5.2 Population structure: The population of *Sclerocaya birrea* appeared essentially young in both land use. However, it was twice times most important in Sahelian area than Agroforestry

systems. These results could be explained by human activities. Farmers believe that the shade of adult trees generally hinders the crop development. Thus, they make all to reduce tree density in agroforestry systems using many destruction techniques such as burning, ring-barking and felling. These practices make that more and more the old individuals were rare and according to the farmers, adult individuals of the species were scarce and often declining in abundance. The quantitative inventory supported the respondents view. The analysis of SCD indicated that the species had a weak population structure. It exhibited an L-shaped slopes (a_1=-0.029 and a_2= -0.031 respectively for agroforestry systems and Sahelian area). Species with weak slopes generally have a poor regeneration potential and may be declining (Tabuti and Mugula, 2007). The Figure 2 showed that there is a higher number of juvenile individuals but these were died out the population before they had recruited into sapling or mature individuals. This loss of juvenile individuals weakened thus the population. For population to maintain itself, it needs to have abundant juveniles, which will recruit into adult size class (Bationo *et al.*, 2001). Similarly, the absence of adult in population affects recruitment into the population by lack of seeds (Mapongmetsem *et al.*, 2011). The wide mortally of seedling may be explained by the constant disturbance of overexploitation for different uses. Most respondents related the precarious status of *Sclerocarya birrea* to overexploitation and land clearance. Grazing could be also important in to disappearance of the juvenile individuals in the nature (Tabuti and Mugula, 2007).

The adult density of *S. birrea* is higher in the Sahelian area. More we go away from village more the density of species increases. These results corroborate with those obtained by Shackleton *et al.* (2003) in Benin. However, both distributions were right-skewed giving evidence of relatively large proportion of smallest individuals. According to Condit *et al.* (1998), many factors such pattern of use, harvest and land use type are susceptible to affect size class distribution of a given plant species. The big-sized individuals found in agroforestry systems could be due to many factors. One such a factor is the level of focus. In the agroforestry systems, the occurrence of adult individuals of *S. birrea* is due to focus of farmers. The harvest of different parts of the species was making with moderation and the juvenile individuals that could recruit into adult individuals were very well kept. In other hand, in agroforestry systems trees benefit from management actions (weeding and fertilization of land) consented to crops (Gouwakinnou *et al.*, 2009). Moreover, other environmental factors such as wild fire could much affect the growth of the species in Sahelian area than in agroforestry systems. The illegal logging that target large individuals for handcrafting purposes could also partly explain the found size class structure.

5.3 Species uses farmer perceptions* and implication for management of *Sclerocarya birrea: *Sclerocarya birrea* is known as a useful species. Despite of its socioeconomic interests, it does not seem to be highly protected by the local communities of Sahelian zone of Cameroon. This assumption is based on the fact that most farmers affirmed that they were not encouraged to protect this species. Someone thought that it was a gift of "Allah" and the resource will always be available (Mapongmetsem, 2005). That was what explained their behaviour opposite to the species conservation. In whole study zone, the measures of collective management of the *Sclerocarya birrea* trees were weakly present and the individual initiatives were timid or even non-existent. The actions led were disparate and summed up in the conservation of some seedlings in the farm. All other forms of domestication were unrecognized of local communities. Only 31 % of the interviewed persons show an interest for the sustainable management of the species. Although the majority does not recognize the necessity to keep *S. birrea* but it confirms nevertheless the importance of this species in their different

activities. For those who show a desire to domesticate the species, they have a little knowledge on the propagation techniques.

The current adult density of *S. birrea* (4.08±0.8 trees/ha) does not seems alarming. However, this situation does not allow to *S. birrea* to remain for a long time. The demographic explosion and the subsequent request of land for agriculture will certainly negatively affect more and more the species density. In agreement with the cry of the local communities, it is important to assess the change of *Sclerocarya birrea* population and to manage sustainably this species. The size class distribution is a good predictor of future population change. It has been widely used toward this end, as it is a shortcut in the absence of direct estimates of population size through time (Feeley *et al.*, 2007). Considered as the first step, the structure of a population combined with size-specific growth rate, spatial distribution and pattern of use and harvest can be used for strong management decisions (Condit *et al.*, 1998; Bitariho *et al.*, 2007; Djossa *et al.*, 2008). Moreover, the diameter size class distribution revealed a high density of juvenile individuals. This situation shows that ecologically the population of *S. birrea* may be regenerated. To booster this individual class to reach the adult category it is necessary to take management decisions and the important management decisions could begin by some studies on the species biology and ecology. Other management actions as transplanting the young plants could be encouraged. Considering the capacity of *Sclerocarya birrea* to regenerate via vegetative propagation patterns (cutting, layering, grafting, suckering, etc.) (Mapongmetsem *et al.*, 1999; Noubissi-Tchiagam *et al.*, 2011), these types of regeneration could be developed for the propagation in agroforestry systems and *ex situ* conservation of *S. birrea* and also for the selection of varieties with interesting criteria such as high yield and fruit quality and rusticity.

6 CONCLUSION

This study permitted to identify the different uses of *S. birreaa* among which the handcraft and human feed were the most cited. The Sahelian area had a higher density of tree than the agroforestry systems. The structure of the individuals showed a dominance of young individuals. The adult individuals density is higher in agroforestry system. The harvest of the species was made at irregular periods and it depends on the farmer. The conservation of the species was again timid or in the worse of the cases non-existent among the local communities. It was therefore necessary and urgent to develop a program of participatory domestication of this plant in the interest of the present and future generations. The implication of the local communities in the management of the species is the key of arch of its conservation. The resident communities have needed to be sensitized in general on the true value of the multifunctional local plants in general and of *Sclerocarya birrea* in particular.

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