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Structure and regeneration of *Parkia biglobosa* (Jacq.) R. Br Ex G Don in Mount Mandara, Cameroon

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A study was carried out in the Mount Mandara area to assess the populations and renewal status of *Parkia biglobosa,* a multi-purpose species. The study was aimed at contributing to the sustainable management of this resource. Transect methods were used to count individuals of *P. biglobosa* in fields. Results showed that the density of *P. biglobosa* was 7 individuals ha^{-1}. The basal area of *P. biglobosa* individuals varied as follows: Mokolo area (21.41 m^2 ha^{-1}) and Roua-plateaux Zoulgo (20.06 m^2 ha^{-1}). In these zones, big trees of *P. biglobosa* with large diameters were quite numerous. The average diameters were 79.14 ± 5.04 cm, and the average height was 13.60 ± 0.96 m. The structure of the distribution among the diameters generally was bell shaped, but the distributions varied in each zone. The greatest number of individuals was observed in the [50-70 cm] and [70-90 cm] diameter classes, with a remarkable increased presence of individuals in class [130-150 cm]. The scarcity of the individuals in the diameter range of 10 to 30 cm was noted in the various zones, with their entire absence in the Roua- Plateaux Zoulgo and Méri zones. The rate of regeneration of *P. biglobosa* was 13 %. This rate was very weak compared to the socio-economic importance of this species. This regeneration rate will not ensure continued population strength of this multipurpose species. This species is proven of importance, but its capacity of regeneration was too low to ensure its sustainability. It becomes imperative to develop effective strategies for its regeneration and conservation.

Key words: Population, dynamic, sustainable management, multi-purpose, *Parkia biglobosa,* Mount Mandara.

INTRODUCTION

In sub-Saharan Africa, trees play an essential role in the life of the rural population. They provide essential foodstuffs, drugs, fodder, and wood-energy and contribute to the maintenance and stability of ecosystems

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(Le Houérou, 1980; Akpo, 1998; FAO, 2005; Gning, 2008; Mbow, 2008; Bakhoum et al., 2012b; Ngom, 2013; Sarr et al., 2013). *Parkia biglobosa* belongs to a group of privileged forest species, because of their multiple and advantageous uses to the local population (Aubreville, 1950). It is the most common species of the agroforest systems and agrosylvicultures, which occupy a significant place in the semi-arid zones and sub humid regions for its capacity of great use to the local populations (Boffa, 2000; Sacande and Clethero, 2007). Its distribution area encompasses the African, Asian and of South American continents. In the Mount Mandara, *P. biglobosa* also seems to be one of the privileged species because of its multiple uses. The populations generally use its fruit as food in welding period (Bergeret and Ribot, 1990; Boffa, 2000). It seeds are fermented to make a cooking spice named "soumbala" or "dawa dawa", made up of a black colour, strong odour, nutritive, tasty and high protein value (Bonkoungou et al., 2002; Steinkraus, 1996a). The medicinal uses of *P. biglobosa* are diversified. It is used to cure digestive tract (diarrhoea, dysentery, abdominal pain) diseases, cardiovascular system diseases, traumatisms and burns, infectious diseases (shingles, malaria, boils, yellow fever, measles, chicken pox, oedemas), paediatric pathologies, symptoms and syndromes (faintness, tiredness, headaches, pain of hip, rheumatism, excessive loss of weight, elephantiasis, beginning of the paralysis (Koura et al., 2011; Mamadou, 2013; Adejumo et al., 2014). The fruits and fermented seeds are consumed and sold. The income generated thus contributes to the improvement of the household's economy and the reduction of poverty (Giffard, 1974; Boffa, 2000; Mamadou, 2013; Adejumo et al., 2014; Koura et al., 2011). The *P. biglobosa* shell fruits or other fruit residue provide many environmental services: it provides a way for the ground to be de-salted for rice way repair and contributes to habitat protection against termite attacks, and acts to suppress bad grass (Mamadou, 2013). Since the repetitive drought cycles, Sahelian farmers have harvested wild fruits and use it to avoid food shortage or as auxiliary sources to cover the food deficit periods (Bergeret and Ribot, 1990; Boffa, 2000; Sawadogo et al., 2008). In the Mounts Mandara, *P. biglobosa* is strongly exploited by the populations for its fruits and particularly its seeds in the transformation of "Dawa dawa". These products are the subject of a trans-border trade. The exploitation of the fruits and seeds of this species tends to intensify the increases in pressure on the resource. It becomes an imperative to provide necessary information for the sustainable management of this important plant. In spite of the significant scientific work load devoted to *P. biglobosa* in its phytogeographical area (Beaulaton and Gutierrez, 2002; Douma et al., 2010; Koura et al., 2013), no scientific study was devoted to the demography and the regeneration status of this species in the Mount Mandara in the Sahelian Zone of Cameroon. However, this species has particular socio-economic importance because of the utilisation of its various products by local populations. This study brings acknowledgement on the potential availability of this species in order to develop the suitable strategies for its conservation and its sustainable management in the Mount Mandara.

The study's aim is to contribute to the sustainable management of this multi-purpose species in the Sudano-Sahelian zone. More specifically it aims to: (1) to determine the structure of the populations of *Parkia biglobosa*; (2) enumerate the seedling and the rejections on stumps for the assessment of its regeneration.

MATERIALS AND METHODS

Study area

Investigations were carried out in the Mount Mandara located between 10°45' 0 " N. and 13°40' 0 " E. In the administrative plan, it covers two regions: North and Far-North and extending on 4 divisions (Mayo-Sava, Diamare, Mayo-Tsanaga in the Far-North region and Mayo-Louti in the North region) (Figure 1). The climate of the Mount Mandara was characterized by the Sudano-Sahelian type and modified by the orogenic effects. Two varieties were known: in the North, the climate was Sahelo-Sudanian type with a period of four months of rainfall and in the South, the Sudano Sahelian type with a period of five months of rainfall. The annual average rainfall was about 800 mm in the Northern part and 1100 mm in the Southern part. The temperatures oscillated between 13°C (January) and 38°C (April); the annual average temperature was 28°C. This vegetation was strongly degraded under the pressure of the anthropogenic actions (cutting for firewood, charcoal, wood service, bush fires and overgrazing) and the climatic threat (Letouzey, 1985; Westphal et al., 1985). The economic activities of the zone were based on extensive agriculture subsistence, extensive breeding, exploitation of resources, craft industry and the small trade, generating a substantial income for the poor rural families.

Data collection

To carry out this study, 40 villages were selected along the Mandara Mountains chains, according to the criteria of accessibility, type of dominant activities, demographics and the presence of some ethnic groups. These villages were gathered in 5 zones as follows: Mokolo; Roua-Plateau Zoulgo; Bourha-Plateau Kapsiki; Hina-Guider; Méri. The dendrometric data were collected along transects of 2000 m length and 20 m of width, on the whole 36 transects were established in various milieu within the basal mount and some mountainous zones. The sites (5 zones) of the investigation were as follows: Mokolo (24 ha), Roua-Plateau Zoulgo (48 ha), Bourha-Plateau Kapsiki (44 ha), Hina-Guider (16 ha), and Méri (12 ha). The stems of *P. biglobosa* were counted in all milieus such as the valleys, plates, plains and in relation to altitude. This species grows in flat terrain, with more than 1000 m of altitude. Along transects, the circumference (≥10 cm) of all *P. biglobosa* trees was measured at breast height 1.3 m from the ground, using a decametre. 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 were established randomly and used to count the seedling and rejections. A distance of 100 m was made between plots. The seedlings, and the trees that had been cut but rejected and left

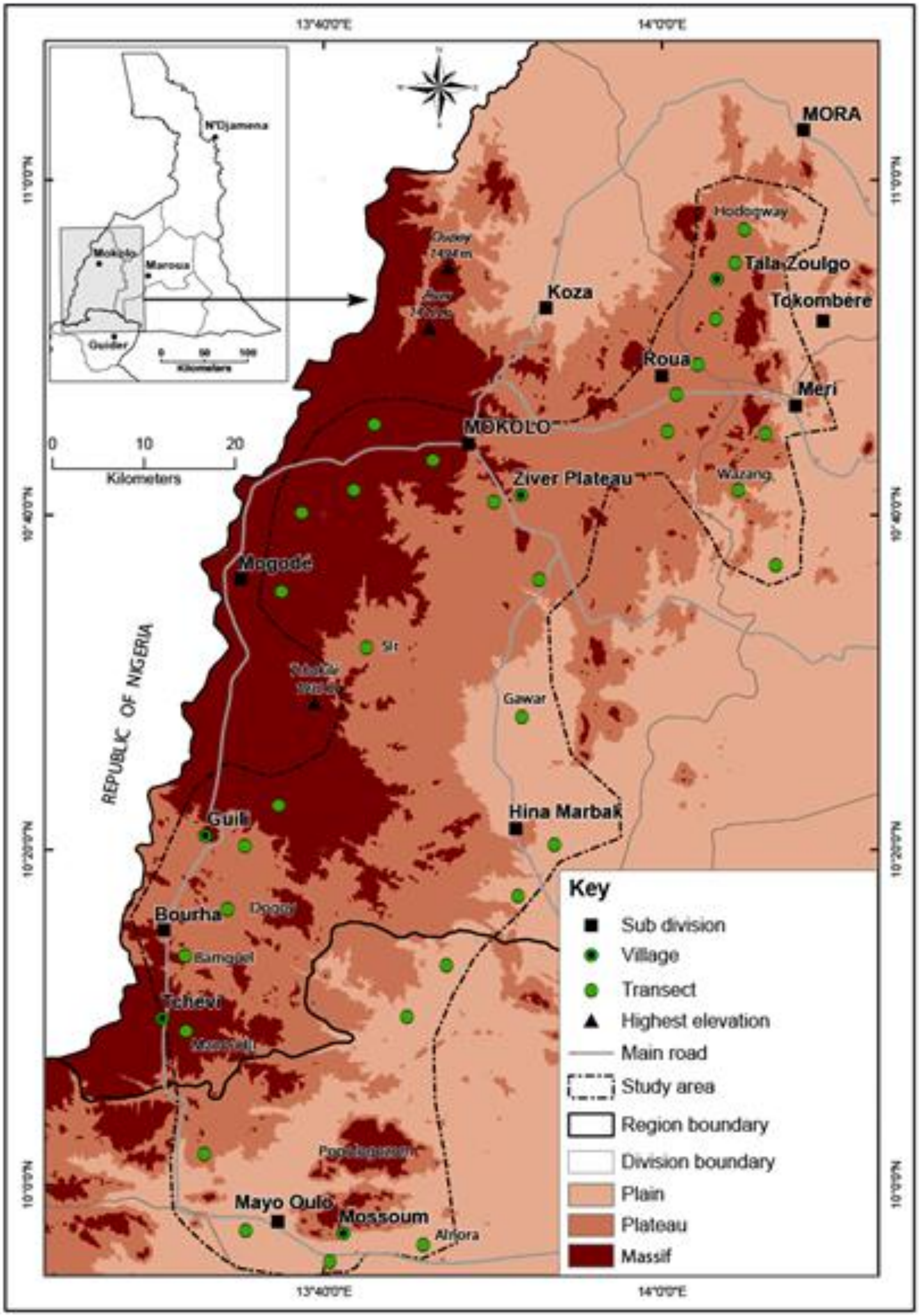

Figure 1. Study area and the transects itinerary in the Mount Mandara.

Table 1. Dendrometric parameters of *P. biglobosa* in the Mount Mandara.

Zone	Density	Average diameter and bar charts (cm)	Basal area (m^2/ha^{-1})	Average height and bar charts (m)	Average tree archway (m)
Mokolo	4.29^b	87.16^a (28.66)	21.41^a	14.76^a (5.12)	14.05^a (5.21)
Roua-Plateaux Zoulgo	6.9^a	81.69^a (25.89)	20.06^a	14.56^a (4.25)	14.13^a (6.48)
Bourha-Plateaux Kapsiki	11.70^a	79.01^a (37.11)	19.40^a	12.15^a (3.68)	11.53^a (5.41)
Hina-Guider	1.38^b	74.80^a (31.10)	18.37^a	13.48^a (4.31)	10.95^a (4.42)
Méri	1.25^b	73.04^a (27.01)	17.94^a	13.07^a (2.74)	10.20^a (3.97)

According to the analyses of variance, the same letters in the same column means similarity and dissimilarity in the contrary cases. The numbers between parentheses are the bar charts.

standing, were counted. The trees that had been cut and the dead trees were also counted.

Data analysis

The dendrometric parameters in particular, the diameter of the tree, basal area (G) and the density of *Parkia biglobosa* were calculated. The basal area (G) was the sum of the surface of the cross sections of *Parkia biglobosa* individuals measured at 1.30 m. It was determined by the formula (Sourou et al., 2016):

$$G = \sum_{i=1}^{n} C_i^{\,2} / 4\pi$$

with G, basal area of the trees within a transect and Ci, the circumference.

Tree density was determined as the number of *P. biglobosa trees* counted per hectare. The regeneration rate and the death rate of the population of *Parkia biglobosa* were calculated and expressed as a percentage. Diameter structure of *P. biglobosa* population was measured by grouping individual trees into 20 cm diameter class sizes, height distributions and tree archways. The distribution was analysed and displayed in the various explored zones using histograms in Microsoft Excel. Other variables such as means and percentages were determined using ANOVA in STAGRAPHICSPLUS 5.5.

RESULTS

Distribution of the population of *P. biglobosa* in the Mount Mandara

In the five explored zones, a total of 993 individuals of *P. biglobosa* were counted. The total density of the individuals in the Mount Mandara was 7 individuals ha^{-1}. In this vegetation, the distribution of *P. biglobosa* varies in the various explored zones as follows: Bourha-plateau Kapsiki (11.70 individuals ha^{-1}), Roua-plateau Zoulgo (6.87 individuals ha^{-1}), Mokolo (4.29 individuals ha^{-1}), Hina-Guider (1.38 individuals ha^{-1}), and Méri (1.25 individuals ha^{-1}) (Table 1). This variability was shown to be statistically significant (p= 0.0021) using analysis of variance. A low density of the populations of *P. biglobosa*is was noted in Hina-Guider (1.38 individuals ha^{-1}) and Méri (1.25 individuals ha^{-1}). These zones were located between the altitude and the plain zones where the rainfall decreases and the vegetation is strongly degraded.

In the Mount Mandara, the average diameter of *P. biglobosa* was 79.14 (5.04) cm. In the five explored zones, the average diameter varies from 73.04 (27.01) cm in Meri to 87.16 (28.66) cm in Mokolo (Table 1). The average diameter was respectively of 79.01 (37.11), 81.69 (25.89) and 74.80 (1.10) cm in Bourha-Plateau Kapsiki, Roua-Plateau Zoulgo and Hina-Guider zones. The difference between the average diameters in the zones was not significant. The average height of the trees was 13.60 ± 0.96 m. This height varied in the various zones from 12.15 ± 3.68 m in Bourha-Plateau Kapsiki to 14.76 ± 5.12 m in Mokolo. The average heights were not significantly different in the various zones. The average tree archway sizes was 12.17 (1.62) m. The tree archway size also varied from 14.13 (6.48) m to 10.20 (3.97) m. These results showed that, in the Mount Mandara, *P. biglobosa* was a large tree. It develops a great height, a large tree archway size and a large diameter. Pluviometry and the anthropogenic pressure seem to be the determining factors for the blooming of this species in its phytogeographic area.

In the Mount Mandara, basal area of *P. biglobosa* in the various zones varies from 17.94 m^2 ha^{-1} in Méri to 21.41 m^2 ha^{-1} in Mokolo. The individuals of *P. boglobosa* had a significant cover in the Mokolo (21.41 m^2 ha) and Roua-plateau Zoulgo (20.06 m^2 ha^{-1}) zones. In these zones, the big trees of *P. biglobosa* with the large diameter were rather numerous. These two zones were characterized by the population's culture in conservation of this species; they were developed for a long period of time in the farmer land and habitation area.

Structure in diameter of *P. biglobosa* in the Mount Mandara

The structure of distribution in diameters of the individuals of *P. biglobosa* of the Mounts Mandara

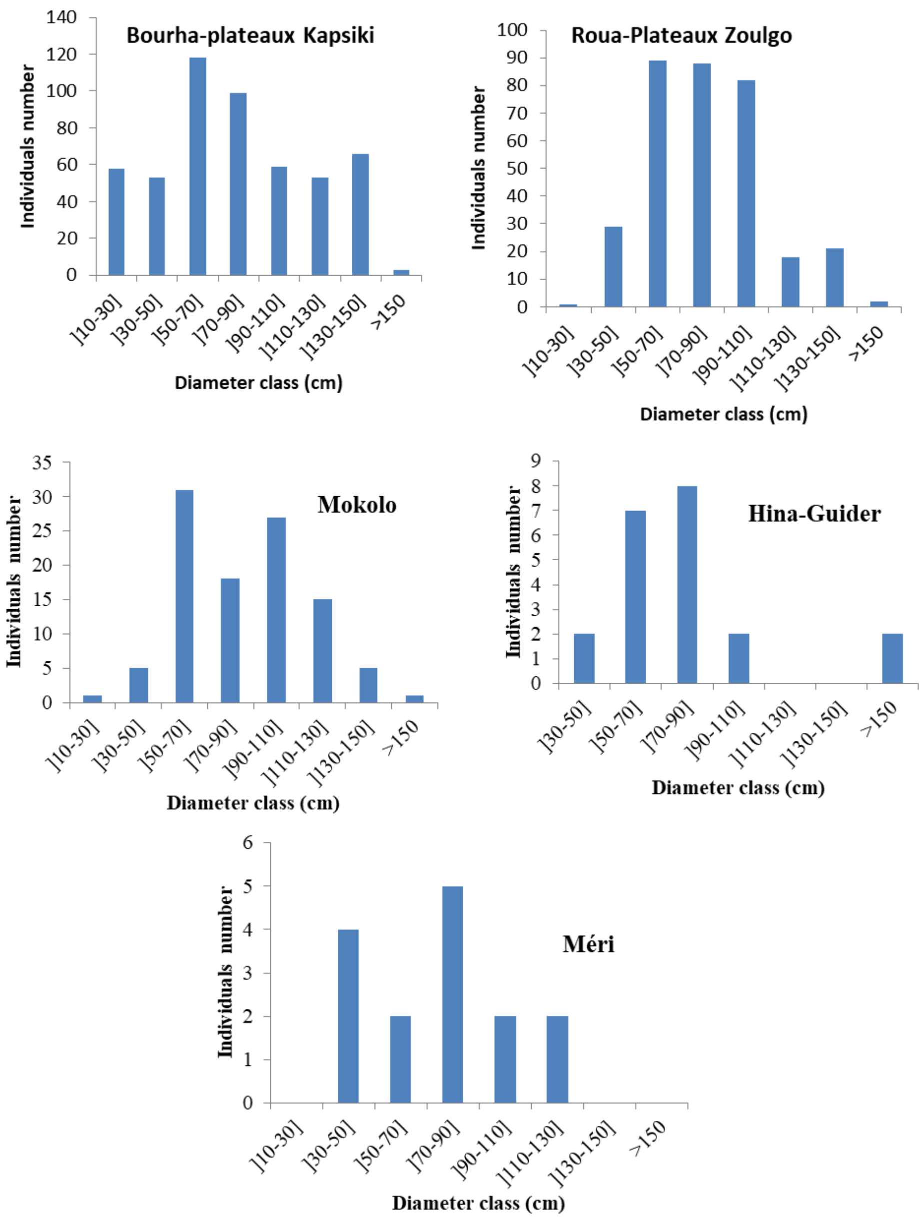

Figure 2. Diameter distributions of *P. biglobosa* in the Mount Mandara.

presented in general a bell shape, but this distribution varied in each zone (Figure 2). They were observed in the diameter classes of [50-70 and 70-90] with a remarkable presence of the individuals in the class [130-150] in Bourha-Plateau Kapsiki with the absence of individuals in this class of Hina-Guider. In the Roua-Plateau Zoulgo zone, the greatest number of individuals was counted between the diameter classes of [50-70] and [90-110]. In the Méri zones, the greatest number of individuals was enumerated in the diameter were noted in the diameter classes of [50-70] and [90-110]. The scarcity of the individuals in diameter from 10 to 30 cm was noted in the various zones with a whole lack in Roua-Plateau Zoulgo and Méri zones. The individuals of *P. biglobosa* generally form a part of the agricultural landscape. Thus, the structures in diameter of the populations of this species translated the importance of its conservation by the local populations, as far as its socio-economic importance is concerned. In a general way, the individuals of large diameters (≥ 150 cm) are rare. The two categories of individuals, regenerated stems and large trees did not have a homogeneous distribution in all the zones. The scarcity or the absence of individuals of small diameter showed that, the natural regeneration of the species was difficult. The seedlings had difficulties of being maintained because of the effects of the dryness

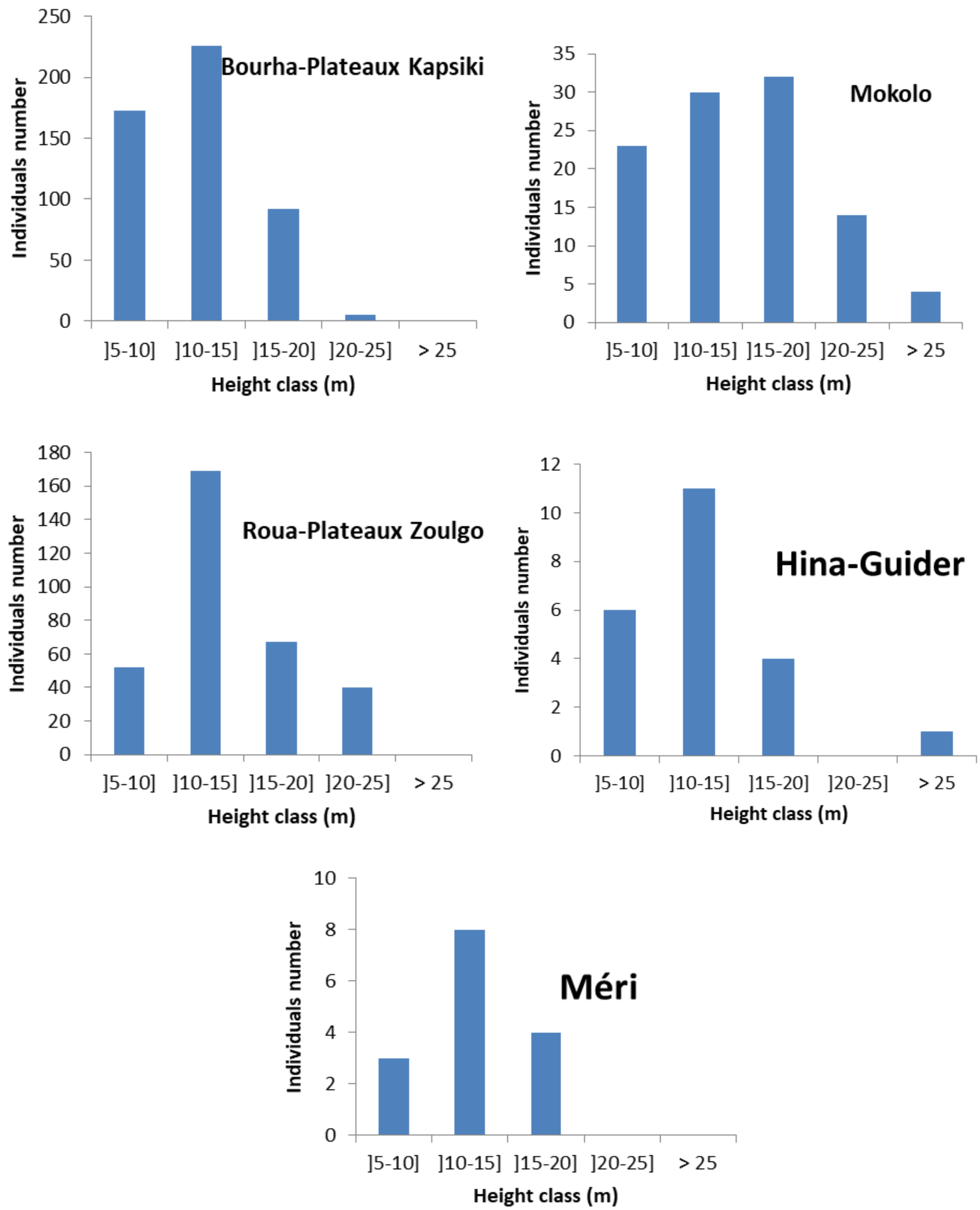

Figure 3. Vertical distribution of *P. biglobosa* in the Mount Mandara.

and the pasture where they were growing during the long period of the dry season. The strong anthropogenic pressure remains also a factor of the regressive evolution of the *P. biglobosa* populations in the Mount Mandara. Under these conditions, it could be an imperative to take important measures in favour of the conservation and the sustainable management of this multipurpose plant.

Structure in height of *P. biglobosa* in the Mount Mandara

The distribution in height of the individuals of *P. biglobosa* followed a pattern of bell shape. It was roughly the same pace as that of the structure in diametric distribution with some particular characteristics (Figure 3). In Bourha-

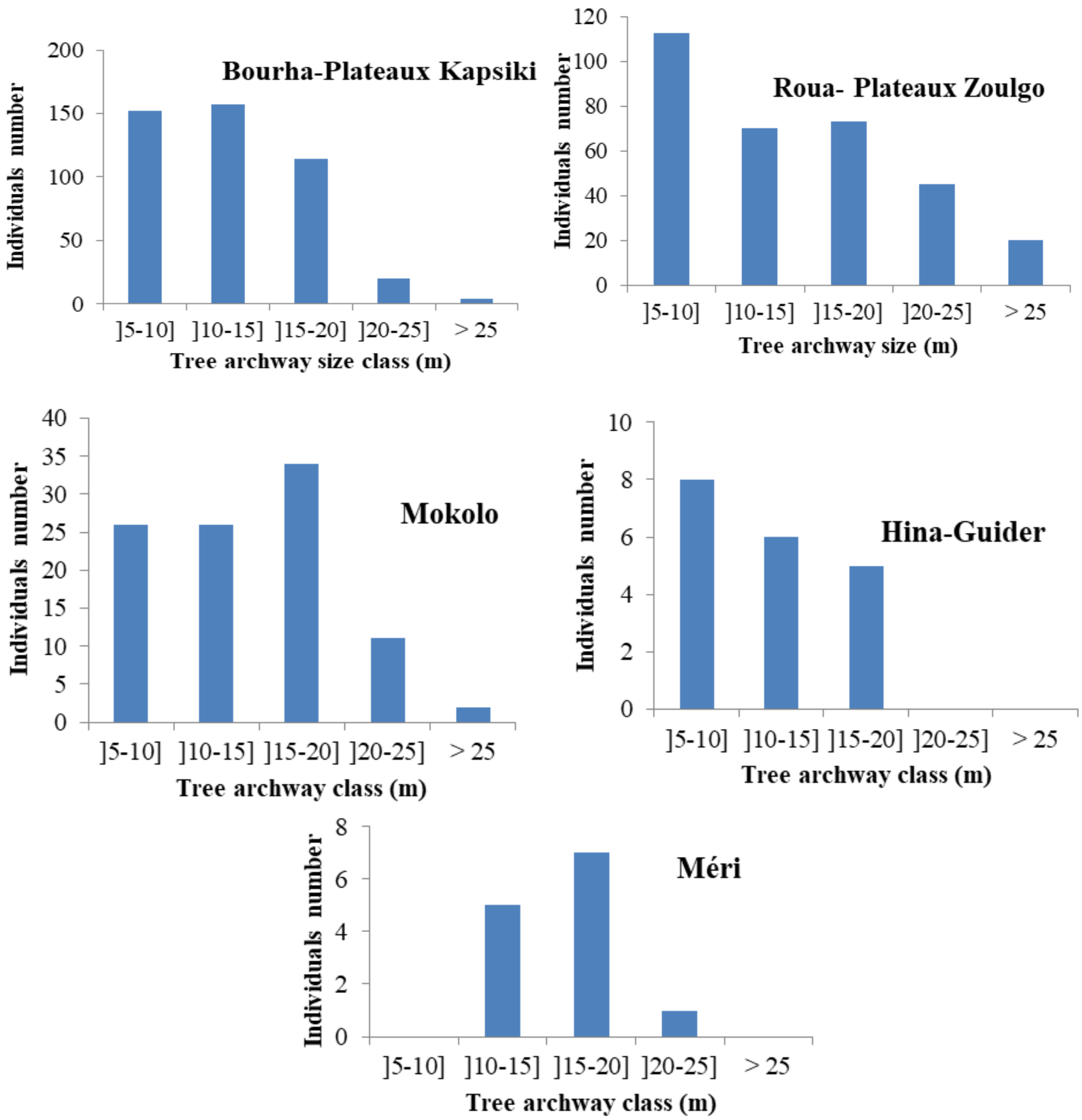

Figure 4. Distribution of the tree archway size study zones.

Plateaus Kapsiki, ZoulgoRoua-Plateau, Hina-Guider and Méri zones, the greatest number of individuals was noted in the class height [10-15 m]. Whereas in Mokolo zone, the classes height [10-15] and [15-20] presented the greatest number of individuals. According to the distribution in diameter, the individuals' height was rarely reduced, 10 m than 20 m were rare. Nevertheless, it should be noted that the younger individuals were more numerous in the Bourha-Plateau Kapsiki and Mokolo than in the other explored zones.

The tendency of the histograms of tree archway size distribution showed that the majority of the individuals concentrate in a general way in the classes [5 -10] and [10 -15]. The variation was very remarkable in Mokolo and Méri zones where the record number of individuals concentrated in the classes of [10-15] and [15-20] with a scarcity of the individuals in the classes of [5 -10] and ≥25 (Figure 4). Broadly, the greatest number of individuals was concentrated around the average of tree archway size (12.17 ± 1.62 m). This variability was shown by the calculation of variance with $p = 0.0161$. These results illustrated the behaviour and the interest which the population of the various zones had on this specie. In certain zones like Mokolo, Roua-plateau Zoulgo, and Hina- Guider, the farmers practised the upholding of the old and unproductive trees by pruning for the renovation and a resumption of fructification, thus contributing to the reduction of the size of the tree archway size.

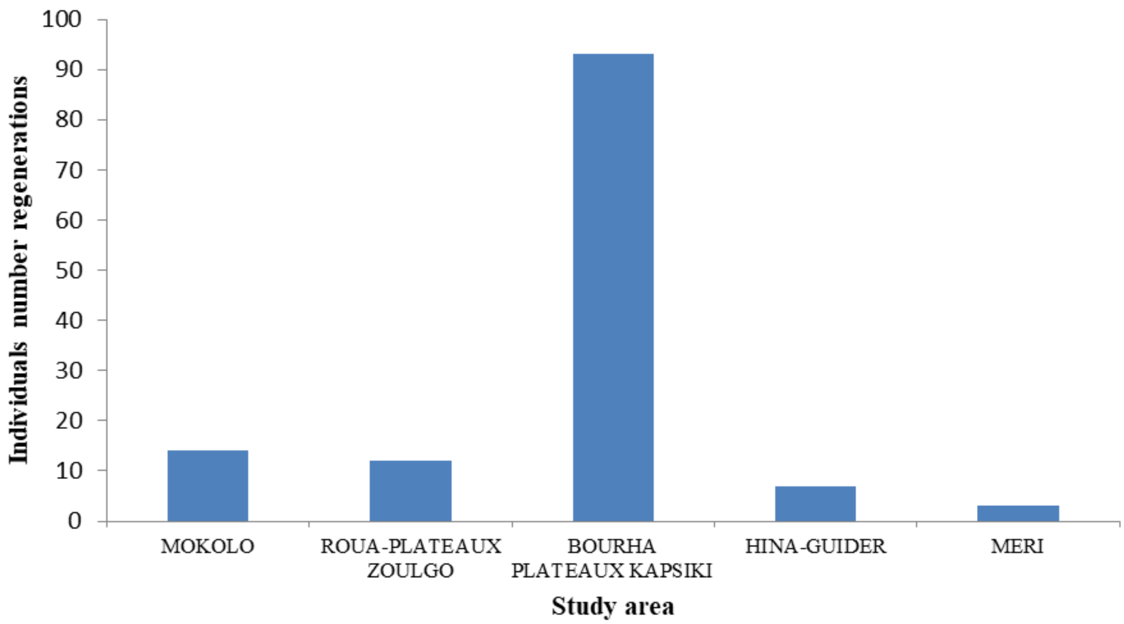

Figure 5. Regeneration status of *P. biglobosa* in the Mount Mandara.

Regeneration status of *P. biglobosa* in Munts Mandara

In the Mounts Mandara, the regeneration rate of *P. biglobosa* was 13%. In the Bourha-Kapsiki zone, the regeneration rate was 9.36% (Figure 5). In the four other zones, the youthful individuals are rare: Mokolo (1.40%), Roua-Plateau-Zoulgo (1.20%), Hina-Guider (0.7%), and Meri (0.3%). The distribution of the seedlings and rejections were significantly different in the five studies zones with $p = 0.0024$. The regeneration rate noted in Bourha-Kapsiki explained the interest which the local populations had for the conservation of *P. biglobosa.*

DISCUSSION

Distribution of population of *P. biglobosa* in the Mount Mandara

The density of *P. biglobosa* was 7 individuals ha^{-1} in the Mount Mandara, this density varied from 11.70 individual ha^{-1} to 1.25 individual ha^{-1} in the various explored zones. These results were near to those obtained by Gbédji (2003) (1 to 5 individual ha^{-1}) in the *P. Biglobosa* parks in Benin; Douma et al. (2010) (1.64 individual ha^{-1}) in a study in Sahelo Sudanese area in Niger and Douamba (2006) (8 individuals ha^{-1}) in Sudano-Guinean zones. These authors justify the low densities obtained due to the fact that, individuals of *P. biglobosa* were subjected to a strong anthropogenic pressure. The wood of this species was required in craft industry to fabricate arts objects. On the other hand, these values of density were definitely lower than those obtained by Koura et al*.* (2013) (39 to 70 individuals ha^{-1}) in various zones in Benin obtained by Ouédraogo (1995) (5 to 25 individuals ha^{-1}) and those of Thiombiano et al. (2010) (37 individuals ha^{-1}), whose work were undertaken in various zones in Burkina Faso. According to these authors, the zones where the density of *P. biglobosa* were high, it had a great socio-economic and cultural value in the life of the population. It was the case noted in the present study where the densities were significant in the zones of Bourha-Plateau Kapsiki and Roua-Plateau Zoulgo, where the plant was of remarkable socio-economic interest for the population. The same observations were made by Koura et al. (2011) where the densities of *P. biglobosa* were high, local knowledge were diversified. In spite of the rocky field, *P. biglobosa* had a remarkable capacity of adaptation in mountainous zone. *P. biglobosa* developed a root system and succeeded in being clutched with the blocks of rocks. In the Mounts Mandara, the volume of rainfall was particularly significant upon the influence of altitude on the climate, making this milieu favourable for the development of *P. biglobosa*. It was found in altitude 1000 m and also in the plains. The studies of Douamba (2006) in Sudano-guinean zone concluded that *P. biglobosa* developed in flat grounds on the clay soils, muddy and muddy argilo that, *P. biglobosa* was not identified in altitude. According to the various results, it was possible to affirm that *P. biglobosa* developed well in a plain and in altitude on various types of ground in the Sudano-Guinean and Sudano-Sahelians zones.

In the Mounts Mandara, *Parkia biglobosa* was a large tree, but a weak number of the regeneration individuals to ensure the renewal of the species were noted. However, *P. biglobosa* developed also a large diameter and great height. These observations were in agreement with Douma et al. (2010) a study of the Tamou rural district in Niger, which were shown that 80% of the listed individuals were large trees and noted a weak recruitment of the juvenile individuals. The occurrence of old trees was remarkable and indicated an elderly of this species populations and a low capacity of regeneration. Seignobos (1982) shows that the abundance of old trees can be considered as an index of threat to the disappearance of this species in the agroforests system of the zone and the result of a shaping by the anthropic activities.

The basal area of *P. biglobosa* in the various zones of Mounts Mandara, varied from 17.94 to 21.41 m^2 ha^{-1}, respectively in Méri and Mokolo zones. The individuals of *P. boglobosa* had a significant coverage in Mokolo (21.41 m^2 ha-^{1}) and Roua-plateau Zoulgo (20.06 m^2 ha^1) zones. In these zones, *P. biglobosa* trees with large diameter were quite numerous. Because of the socio-economic importance of this species, the populations long times had developed the ethnicity of its conservation since a long time ago. These results were higher than those of Koura et al. (2013) which found 4.93 to 12.38 m² ha^{-1} in *P. biglobosa* parks in Benin.

The structure of distribution in diameter of *P. biglobosa* in the Mounts Mandara shows that the greatest number of individuals was observed in the diameter class of [50-70] and [70-90] with a remarkable presence of individuals in class [130-150] in Bourha-Plateau Kapsiki zone with the lack of individuals in this class in Hina-Guider. The scarcity of individuals in diameter 10 to 30 cm was noted in the various zones with quasi absence in Roua- Zoulgo Plateau and Méri. The individuals of *P. biglobosa* were found in the agricultural landscape. These results were confirmed by those of Koura et al. (2013) which had shown a similar structure in diameter and concluded that, the structures in diameter of *P. biglobosa* population translated the impact of the management of this species by farmers. The local management did not worry about the regeneration status of the species and presented a stunning deficit in the lower diameter classes ranging between 10 and 20 cm (Koura et al., 2013). The scarcity or the absence of the seedling individuals showed that the natural regeneration of *P. biglobosa* was difficult. Seedlings had difficulties of being preserved because of the effects of dryness and pasture which they faced during the long period of the dry season. The strong anthropogenic pressure remains also an important factor of the regressive evolution of the *P. biglobosa* populations in the Mounts Mandara. It was an imperative under these conditions of taking measures in favour of the conservation and the sustainable management of the plant. If provisions were not taken for the sustainable management, the species will extinct. The same reports were made by Thiombiano et al. (2010) on ageing and instability of *P. biglobosa* populations in Burkina Faso. Sambou et al. (2007) in Senegal and Oumarou et al., (2009) in Burkina Faso also found that *P. biglobosa* populations in savannas had a regressive structure. Human activities through the anarchistic exploitation of trees and the introduction of animals seem to be the causes of this regression (Douma et al., 2010).

Regeneration status of *P. biglobosa* in the Mount Mandara

The regeneration rate of *P. biglobosa* in the Mount Mandara was weak and could not permit ensure the sustainability of this significant species. The seedlings were confronted during a year to the climatic threat such as dryness and weak rainfall and to the anthropogenic activities pressure. The survival of the seedlings between the rainy and dry seasons was difficult. Even if the seeds germinated in the raining season, during the dry season, the seedlings in their majority perished. Indeed, seedlings were grazed, trampled by animals in pasture, farmers exploited intensively *P. biglobosa* seeds; this dropped the potentiality of seeds germination in the fields, was and a probable scarce of seeds sprouted to ensure the regeneration. But it should be noted that, in the Mount Mandara the regeneration of *P. biglobosa* was natural and non-participative taking into account the interest which the populations developed around the plant. It was an imperative to develop the adequate strategies to stimulate the populations to contribute significantly to the assisted regeneration of *P. biglobosa.* The regeneration by rejections after the cutting of *P. biglobosa* was not identified in fields. However, the renovation of the old individuals following a pruning to obtain young branches able to produce more fruits was more frequent in the share of the study zones. This strategy of conservation contributed to an increase in the productivity of the individuals existing but was not of great importance in the regeneration of the potential on individuals of *P. biglobosa* in the Mounts Mandara. Ouédraogo (2006) and Oumarou et al. (2009) shows in their work that the seedlings undergo the combined action of the dryness, fires and predatory (cattle, insects, rodents, mushrooms).

Conclusion

The enumeration of the potential available of *P. biglobosa* along transects, in the various zones of the Mount Mandara, showed that this species was well distributed. This distribution correlated the socio-economic importance that farmers in the various zones had on this species and took part in its conservation. *P. biglobosa* sprouted as well on flat ground as in altitude up to 1000 m. *P. biglobosa* was a large tree in the Mount Mandara, it developed a large diameter. *Parkia biglobosa* populations were composed in majority of the growing old individuals of big size. The structure of distribution and the potential regeneration of *P. biglobosa* showed that the renewal of plant was weak and that the population was subjected to anthropogenic activities and the climatic risks which impact on the sustainability of the species. However, the populations practised the renovation of old trees by pruning to obtain younger branches able to produce more fruits. This strategy of conservation contributed to an increase in the productivity of existed individuals of *P. biglobosa* in the Mount Mandara. It was an imperative to develop the strategies of regeneration and conservation *P. biglobosa* in the Mount Mandara. The popularization of the products of the plant, a plan of afforestation, the production of nursery trees and the encouragement of farmers in the preservation of the potential availability were advisable.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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