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ECOLOGY AND STRUCTURE OF *DETARIUM MICROCARPUM* GUILL. & PERL. POPULATION IN THE MBE PLAIN OF THE ADAMAWA, CAMEROON

Georges Maxime Lamy Lamy[1,4*], Adoum Dona[2], Rosette Ndjib[1], Martin Thierry Ottou Abe[1], Talba Dalatou[3], Constantin Amougou Alega[4], Guidawa Fawa[4], Obadia Tchingsabé[5], Leila Zambou Zebaze[1], Phalone Kenne Meli[1], Germo Justine Nzweundji[1], Néhémie Tchinda Donfagsiteli[1], Jason Carver Aaron[1], Bernard Dongmo[1], Hubert Jean Claude Mbita Messi[1], Adamou Ibrahima[4] & Pierre Marie Mapongmetsem[4]

[1]*Center for Research on Medicinal Plant and Traditional Medicine, Institute of Medical Research and Medicinal Plants Studies, P.O Box: 13033 Yaounde-Cameroon*
[2]*Department of Life and Earth Sciences, Faculty of Life Sciences, Earth and Territorial Planning, ATI University of Science and Technology, Chad, P.O Box: 9957, Ati, Chad*
[3]*Department of Industrial Chemistry and Environment, ENSAI, P.O. Box: 454, Ngaoundéré*
[4]*Department of Biological Sciences, Faculty of Science, University of Ngaoundere, P.O. Box: 454 Ngaoundere, Cameroon*
[5]*The Institute of Agricultural Research for Development (IRAD), Nkolbison, P.O. Box: 2067 Yaounde, Cameroon*
**Corresponding author, geomaxlamy@gmail.com*

Abstract.

Background: *In Africa,* Detarium microcarpum *Guill. & Perr. is a species of high cultural, ecological, and socio-economical importance. This led to its over-exploitation, increasing in situ rarity of this species. As a consequence, a conservation alert is increasingly reported across the continent due to the risk of extinction of this multipurpose plant. Unfortunately, indicators of regeneration and conservation guidelines for this species have not been developed yet. The objective of the study was to evaluate the habitat, population structure, and dendrometric characteristics of the plant which are indicators of sustainable conservation.*

Methodology: *A floristic inventory, as well as the vegetation transect method, was used in the villages Def, Karna Manga, and Karna Petel located in Adamawa, Cameroon. The analysis of variance was used to compare dendrometric characteristics across villages.*

Results: *A total of 109 individuals of the plant were counted with a density of 4 individuals per hectare. No plant individuals regenerated in human-controlled habitats (bush fields and home gardens). Three species (*Bombax costatum*,* Piliostigma thonningii*, and* Terminalia macroptera*) were the most frequent accompanying species, as well as the Caesalpiniaceae family. Dendrometric characteristics showed a statistically significant difference ($p < 0.05$) among sites. Regardless of the variable studied, the structure of the* D. microcarpum *population was unstable and its in situ conservation was more successful in Karna Manga.*

Conclusion: *Conservation indicators (habitat, population structure and dendrometric characteristics: crown diameter, diameter at breast height, the height of first large living branch, and tree height) revealed that in situ conservation of* D. microcarpum *population was not sufficient to maintain this species in the study area. For sustainable conservation, less expensive and plant-specific* ex situ *domestication techniques are recommended to maintain species persistence in the studied region.*

Key words: *Extinction risk, conservation biology, biodiversity loss, in situ conservation, preventive ecology, vegetation transect.*

INTRODUCTION

For any conservation science, in principle, the overall goal of conservation ecology is to preserve all life on Earth. This goal can be achieved by preventing species extinction, which is of global concern, characterized by causes, manifestations, and consequences. Globally, the causes of extinction of biodiversity, especially plant biodiversity, are geographically and temporally related (Sax & Gaines 2008; Le Roux et al. 2019). For instance, in Oceania, introduced plants, at a rate of 89%, are the main cause of the extinction of local plants (UNEP-WCMC 2016) because of competition for resources. In a study conducted in parts of Europe, 467 vascular plants were classified as threatened while 436 were in decline due to urbanization, tourism, etc. (Bilz et al. 2011; UNEP-WCMC 2016). In Africa, the uncontrolled harvesting of medicinal and aromatic plants is the main threat to the survival of many, mainly endemic species (UNEP 2010). According to multiple studies, anthropogenic factors directly or indirectly caused most of the plant extinction, compared to natural causes, e.g. droughts, winds, etc. (Sax & Gaines 2008; Sodhi et al. 2009). The manifestation of extinction occurs when the last existing member of a species disappears (Ehrlich 1981; Jablonski 2004; Normile 2008). However, this disappearance does not occur suddenly but is followed by warming signs (e.g. habitat destruction, a decrease of dominance, etc.; Tilman et al. 1994). The total disappearance of a plant *in situ* would lead to a chain of consequences, cultural, economic, ecological, political, and social. For example, on the ecological level, this disappearance could also lead to the disappearance of companion species with which there were interactions essential to the balance of an ecosystem.

At the socio-economic level, the World Health Organization reports that in Africa, medicinal plants play an extremely important role in public health policies (WHO 2003). Since the African populations mostly use local plants for their health, the leaders of the countries of Africa, especially sub-Saharan Africa, are investing more and more financial resources in research on medicinal plants. The disappearance of such plants would therefore have very serious consequences on the primary health of the 80% of local populations who, for the tradition and lack of modern medicinal facilities depend on medicinal plants. Instead of waiting to react to the consequences of human actions, preventive conservation ecology allows us to anticipate them. Indeed, in the short term, it makes it possible to prevent these actions from becoming subjects of major concern. Especially since there is a serious gap in the capacity for *ex situ* plant conservation, especially in Africa, parts of Asia, the Caribbean, Latin America, and the Middle East (Secretariat of the Convention on Biological Diversity 2009). The International Union for the Conservation of Nature has developed a guide: the Red List of Species at 'Risk of Extinction' (IUCN 1989), due to the scientific problem posed by the risk of extinction.

In Africa, *Detarium microcarpum* Guill. & Perr. (Caesalpiniaceae) is a multipurpose agroforestry plant still living *in situ* and highly valued by local populations (Kouyaté 2005; Bastide & Ouédraogo 2008; Kini et al. 2010; Agbo et al. 2017). It reaches the height of 5 to 10 m (Kouyaté 2002; Kouyaté 2007) and its fruits weigh from 0.67 to 1.17 g (Ajani et al. 2019). As reported by Ky-Dembele (2011), *D. microcarpum* is distributed throughout Africa in semi-arid and sub-Saharan areas from Senegal in Cameroon to eastern Sudan. In Benin it colonizes lateritic soils (Amahowé et al. 2012; Agbo et al. 2019), while in Mali it is an indicator of fertile soils. In Cameroon, precisely in the Sudano-Guinean savannas of the Adamawa, *D. microcarpum* compromise a prominent element of the local population socio-economic life (Gautier et al. 2002; Mapongmetsem et al. 2010; Mapongmetsem et al. 2012). Unfortunately, its persistence is threatened because of over-exploitation by illegal cutting of firewood (Mapongmetsem et al. 2008; Fawa et al. 2015; Mapongmetsem et al. 2015; Lamy et al. 2020). The risk of *D. microcarpum* extinction is increasingly reported across Africa (Rapport du Tchad 2016; Agbo et al. 2017). Recently, this plant has been mentioned among the priority wild species for domestication in the Sahel (Atangana et al. 2014; Agbo et al. 2019). Despite multiple extinction risk alerts on *D. microcarpum* across the continent, the plant's status is not yet clearly defined by the IUCN (N'guessan 2019; Kone et al. 2020). According to many authors assessment of the habitat, the population structure and the dendrometric characteristics (diameter of the crown, diameter at breast height, height of the first large living branch, and height of the tree), the conservation status of a plant in its natural environment or *ex situ* are missing (Annapurna et al. 2013; Heywood 2014; Heywood 2015). Studies carried out on this species did not provide the indicators of conservation (habitat, population distribution, structure, and dendrometric characteristics). Therefore, this study aimed to contribute to the conservation of *D. microcarpum* through the improvement of knowledge *in situ*. Comparison of the habitat, population structure, and dendrometric characteristics of *Detarium microcarpum* in three localities could help to determine where the plant conservation is locally the most efficient, to indicate sustainable *in situ* conservation, and then to conclude local (study area) and global (areas of the global distribution of the plant) consequences.

MATERIAL AND METHODS

Study sites

The sites in which the investigations were carried out were in the Mbe plain, notably in the villages of Def, Karna Manga, and Karna Petel (Fig. 1). The district of Mbe is located about 70 km north of the capital of the Adamawa Region (Cameroon). The Cameroonian Adamawa is located between 6° - 8° N and 10° - 16° E. It covers an area of 62 km^2. Its altitude range from 900 to 1500 m a.s.1. The climate is Sudano-Guinean, with an annual rainfall of 1600 to 1800 mm, spread over seven to eight months (Deffo et al. 2009). However, in the Mbe plain the climate is typically Sudanian. The Adamawa Region is sparsely populated with 12.6 inhabitants per km^2 (Moudingo 2007). The main economic activity in this region is cattle breeding. The soil in the region is mostly red ferralitic structures developed on old basalt (Yonkeu 1993). Various types of vegetation are observed in this region. They range from grasslands through shrubby savannas to wooded savannas dominated by

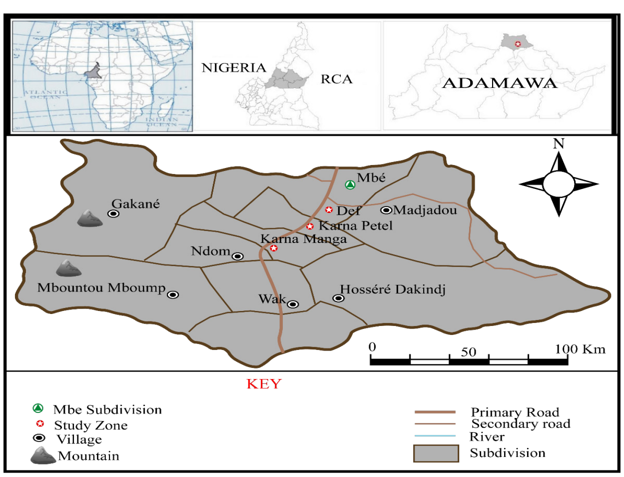

Figure 1: Locality of the study site.

Daniellia oliveri (Caesalpiniaceae) and *Lophira lanceolata* (Ochnaceae) (Letouzey 1968). The density of these species is decreasing due to anthropogenic action (Mapongmetsem et al. 2006).

Floristic inventory

The floristic inventory and the vegetation transect method were used in three sites (Def, Karna Manga, and Karna Petel) according to the methods of Fiers (2003) and Jouret (1972). Depending on the presence of at least one individual of *D. microcarpum* per transect, respectively 17 (Karna Manga), four (Karna Petel), and ten (Def) plots were established in the three sites. All habitats (bush fields, open forest, forest gallery, etc.) of the plant encountered in each plot were recorded. The method used consisted of drawing a 100 m long line, placing stakes, each 2 m long, on the two ends of the line 100 m apart. The string used to connect the stakes was stretched at ground level along the line and at regular intervals (every 1 m), a 2 m stick was placed and all plants encountered were noted (Ottorini 1978) along the line. In particular, the floristic inventory was extended to 5-10 cm on each side of the line. We recorded in the plots of each of the sites all the individuals of *D. microcarpum* with their dendrometric characteristics (height of the tree, diameter of the crown, height of the first large living branch, and diameter at breast height) touching the line or located at the widened edges as well as its companion species. From the stake fixed at one end, another stake connected to the previous one by a string was also fixed on the opposite side. Thus, within the square formed (100 m x 100 m), all the plant species encountered were listed (Archaux et al. 2007). The density per hectare was considered as the number of individuals of *D. microcarpum* present in an area of 100 m x 100 m (1 ha). The calculation consisted of dividing the total number of individuals of the plant counted in a site or locality by the number of total plots made in this site. We measured *D. microcarpum* diameter at breast height (DBH). For multi-trunk trees, we assumed that the average DBH was the value for a particular tree. The diameter of the crown (DC) was determined by measuring four perpendicular crown radii. The height of each plant was measured using a dendrometer. Finally, the height of the first large living branch (HFLB) was measured. Indeed, starting from 1.3 m from the ground, we used a decameter to measure the first large leafy branch that we met on each tree of the plant. According to

Kouyaté (2005), this measurement provides information on the accessibility of the tree. When HFLB is higher than 1.3 m from the ground, people tend to cut down the tree to pick the fruit.

Data analysis

The collected data were processed using Excel software, while the analysis of variance and Tukey *posteriori* tests were performed using the Statgraphics Plus 5.0 program. Mean values were followed by the standard error.

RESULTS

Habitat and population distribution of *D. microcarpum* in the Mbe plain

Habitat of *D. microcarpum* in the plain of Mbe

According to this study, five habitat types (bush fields, woodland, gallery forest, home garden, and wooded savanna) were identified (Table 1). In all these habitats, a total of 109 individuals were recorded respectively at Karna Manga (54), Def (48), and Karna Petel (seven). Regardless of the locality, the habitats hosting more individuals of *D. microcarpum* were respectively: wooded savanna (62), woodland (26), and gallery forest (21). No *D. microcarpum* individual was found in bush fields and home garden.

Species co-occurring with *D. microcarpum* in the Mbe Plain

Within 17 plots surveyed in the Karna Manga site, 54 individuals of the plant were recorded. Thus, in all the 17 plots visited, there was at least one individual of this species. In contrast, *D. microcarpum* was recorded only in 4 and 10 plots in the Karna Petel and Def sites, respectively. As for the accompanying species of *D. microcarpum*, 21 species were recorded (Table 2) with 13 families including Anarcardiaceae (1), Annonaceae (1), Arecaceae (1), Caesalpiniaceae (6), Combretaceae (2), Sapotaceae (1), Eurphorbiaceae (1), Malvaceae (1), Meliaceae (1), Mimosaceae (2), Moraceae (1), Myrtaceae (2), Rubiaceae (1). Thus, the family Caesalpiniaceae was the most represented in the study area.

Concerning the density per hectare of the companion species, the number of individuals of three species (*Bombax costatum*, *Piliostigma thonningii* and *Terminalia macroptera*) was the highest.

Dendrometric characteristics of *D. microcarpum* in the Mbe Plain

Statistically, regardless of the dendrometric parameter (DC, DBH, HFLB, heights) evaluated *D. microcarpum* in Karna Manga the Def and localities and then between the Karna Manga and Karna Petel localities. On the other had higher values than in the Def and Karna Petel localities. The two latter did not differ statistically significantly. Mean DC in all study sites was 0.3 ± 0.05 m (Table 3). DC ranged from 0.51 m (Karna Manga) to 0.15 m (Karna Petel). Mean DBH was of 0.37 ± 0.08 m across all three study sites and was almost twice higher (0.64 ± 0.08 m) than in Karna Manga and similar (0.23 ± 0.08 m) as in Def and Karna Petel. A Mean HFLB varied from 0.35 ± 0.13 m (Karna Petel) to 1.003 ± 0.13 m (Karna Manga), passing by 0.82 ± 0.13 m (Def), and in all three study sites was 0.72 ± 0.13 m. Mean tree height was of 4.96 ± 0.94 m in study sites. The lowest mean tree height of *D. microcarpum* was in Karna Petel (2.18 ± 0.94 m). intermediate in Def (4.59 ± 0.94 m), and the highest was in Karna Manga (8.12 ± 0.94). The analysis of variance revealed a statistically significant difference ($p< 0.05$) among sites for all dendrometric traits studied.

Structures of *D. microcarpum* stands

In the DBH structure of *D. microcarpum* in the study area (Fig. 2) 5-10 cm were the most frequent. This number decreases respectively from 23 (Karna Manga), 20 (Def) to 3 (Karna Petel) individuals. Thus, trees with the highest DBH are gradually dis-

Table 1: Number of *D. microcarpum* individuals recorded in particular habitat and locality in the Mbe plain.

Habitat	Localities			Total
	Djef	Karna Manga	Karna Petel	
Bush fields	0	0	0	0
Woodland	10	14	2	26
Gallery forest	10	10	1	21
Home garden	0	0	0	0
Trees savanna	28	30	04	62
Total	**48**	**54**	**07**	**109**

Table 2: Structure of *D. microcarpum* according to DBH in the Mbe Plain.

Species and family names	Localities Karna Manga (17 plots)		Karna Petel (4 plots)		Def (10 plots)	
	Indiv. Numb.	Den/ha	Indiv. Numb.	Den/ha	Indiv. Numb.	Den/ha
Detarium microcarpum (Caesalpiniacea)	54	3.2	7	1.8	48	4.8
Albizya zygia (Mimosaceae)	20	1.7	14	3.5	18	1.8
Annona senegalensis (Annonaceae)	20	1.7	13	3.3	18	1.8
***Bombax costatum* (Arecaceae)**	**60**	**3.5**	**40**	**10**	**13**	**1.3**
Borassus aethiopum (Arecaceae)	40	2.4	37	9.3	38	3.8
Butyrospermum paradoxa (Sapotaceae)	20	1.7	16	4	18	1.8
Combretum nigricans (Combretaceae)	40	2.4	32	8	20	2
Daniellia oliveri (Caesalpiniaceae)	40	2.4	34	8.5	38	3.8
Ficus thoningii (Moraceae)	18	1.1	20	5	10	1
Grewia bicolor (Malvaceae)	40	2.4	28	7	39	3.9
Hymenocardia acida (Euphorbiaceae)	20	1.7	19	4.8	18	1.8
Isoberlinia doka (Caesalpiniaceae)	40	2.4	w38	9.5	35	3.5
Khaya senegalensis (Meliaceae)	15	0.9	40	10	38	3.8
Lannea acida (Anacardiaceae)	40	2.4	39	9.8	36	3.6
Nauclea latifolium (Rubiaceae)	20	1.7	15	3.8	16	1.6
Parkia biglobosa (Mimosaceae)	18	1.1	16	4	16	1.6
***Piliostigma thonningii* (Caesalpiniaceae)**	**60**	**3.5**	**58**	**14.5**	**59**	**5.9**
Pseudrela kotchii (Caesalpiniaceae)	20	1.7	18	4.5	15	1.5
Pterocarpus lucens (Caesalpiniaceae)	33	1.9	38	9.5	40	4
Senna sangueana (Caesalpiniaceae)	40	2.4	37	9.3	38	3.8
Syzygium guineense var. *macrocarpum* (Myrtaceae)	20	1.7	20	5	20	2
***Terminalia macroptera* (Combretaceae)**	**60**	**3.5**	**60**	**15**	**60**	**6**

Abbreviations: DC (diameter of the crown); DBH (diameter at breast height); HFLP (height of the first large living branch). Results followed by the same letter on the vertical are do not differ statistically significantly at p=0.05 level according to the Tukey *posteriori* test.

appearing in the study area and are present only in Karna Manga. Moreover, the survival of trees with a 5 cm DBH < (young individuals) and those ≥ [16-20] cm (adult individuals) is not assured.

The DC of the species (Fig. 3) revealed that there is a progression from young trees (DC < 0.5 m) of *D. microcarpum*, through adult trees ([0.5-1], [1.1-1,5] and [3-3.5]) to a progressive disappearance of old trees (DC > 3.5 m). Apart from the intervals [1-1.5], [1.6-2] and [2.1-2.5], where the adult individuals of the plant have a high DC at Def, the locality of Karna Manga is in a top position for the other intervals sheltering both the young individuals as well as the adult and old ones.

There is a progressive decrease in the number of individuals of *D. microcarpum* from large heights in the locality of Karna Manga (Fig. 4). On the other hand, in the localities of Def and Karna Petel, one finds first in small numbers, individuals of small heights (< 5 m), then those of medium heights (between 6-10 m) in the majority, and finally trees of largest heights (> 10 m) in the minority. However, while the maintenance of young and old individuals of the plant is not assured in the localities of Def and Karna Petel, it is assured for adult individuals.

The number of individuals of the plant having a height of the first large living branch (HFLB) 1-1.3 meter is the most important whatever the locality (Fig. 5). However, this number is extremely small for HFLB > 1.3 m.

DISCUSSION

Habitat preferences of *D. microcarpum* in the plain of Mbe

The results of our study showed that there are no *D. microcarpum* individuals in human-controlled habitats (bush fields and home gardens), but only in natural habitats (bush fields, open forest, and forest gallery). The consequence in human-controlled habitats could be that, the plant not being known to future generations in the study area. To avoid this risk of cultural and ecological extinction, domestication

Table 3. Mean (± standard error) values of *D. microcarpum* dendrometric characteristics in the Mbe plain.

Sites	Dendrometric characters of *D. microcarpum*			
	DC (m)	DBH (m)	HFLB (m)	Height (m)
Def	0.24 ± 0.05[b]	0.23 ± 0.08[b]	0.82 ± 0.13[b]	4.59 ± 0.94[b]
Karna Manga	0.51 ± 0.05[a]	0.64 ± 0.08[a]	1.003 ± 0.13[a]	8.12 ± 0.94[a]
Karna Petel	0.15 ± 0.05[b]	0.24 ± 0.08[b]	0.35 ± 0.13[b]	2.18 ± 0.94[b]

Abbreviations: DC (diameter of the crown); DBH (diameter at breast height); HFLP (height of the first large living branch). Results followed by the same letter on the vertical are do not differ statistically significantly at p=0.05 level according to the Tukey *posteriori* test.

seems to be a recommended option (Vodouhè et al. 2011). For this purpose, less expensive domestication techniques (air layering, stem cuttings, etc.) that are accessible to local populations should be explored *ex situ*. This analysis is in agreement with the previous studies on the *D. microcarpum* domestication (Gautier et al. 2002; Bationo et al. 2001). It would therefore be essential to initiate conservation programs for *D. microcarpum* throughout the world in its favourable distribution areas.

Density of *D. microcarpum* and accompanying species in the Mbe plain

D. microcarpum is more widespread in the Karna Manga than in other study sites. The highest density per hectare was noted in the Def site. According to Hotra et al. (2003), plant growth is determined by abiotic factors that affect plant density. Therefore, the conservation of *D. microcarpum* could be a function of abiotic factors (soil types, vegetation, climate, etc.) at the local level (study area). For a harmonized monitoring of its conservation, domestication of the plant is recommended.

The results reflect that locally (study area), *D. microcarpum* occurs mainly with species representing Caesalpiniaceae family. Therefore, globally (semi-arid and sub-Saharan areas), the presence of species of the Caesalpiniaceae family would be an indicator of sites suitable for *D. microcarpum* conservation. The results found on the families of companion species are in agreement with those of N'dri & Gnahoua (2009). The three most frequently co-occurring species in the study area would be an indicator of *D. microcarpum* conservation. In southern Mali, the regeneration rate of *D. microcarpum* in four localities where its companion species were found

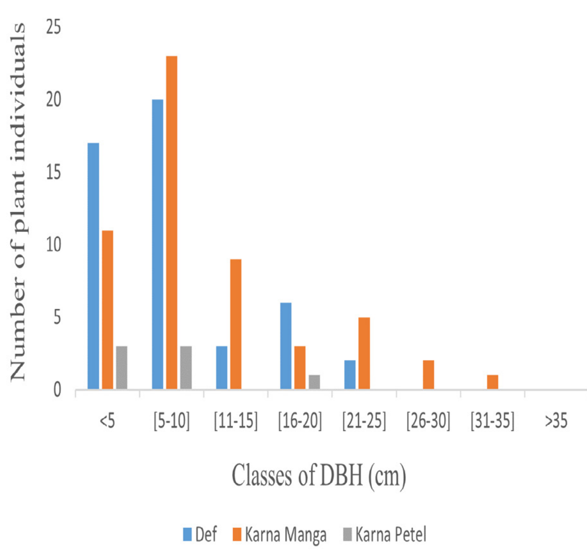

Figure 2: Structure of *D. microcarpum* according to DBH in the Mbe Plain.

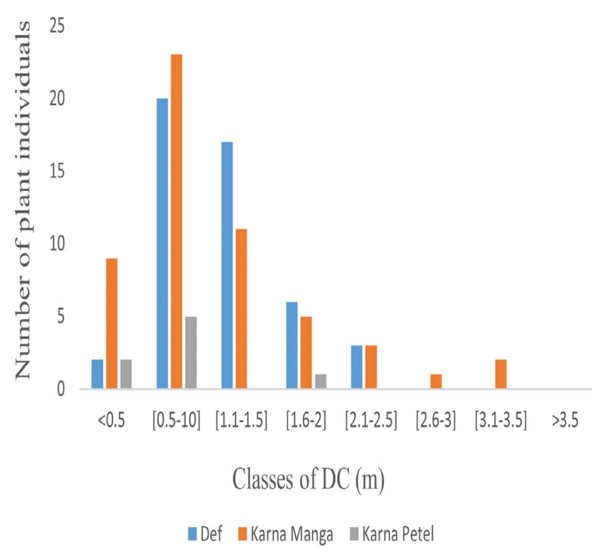

Figure 3: Structure of *D. microcarpum* according to the diameter of the crown (DC) in the Mbe plain.

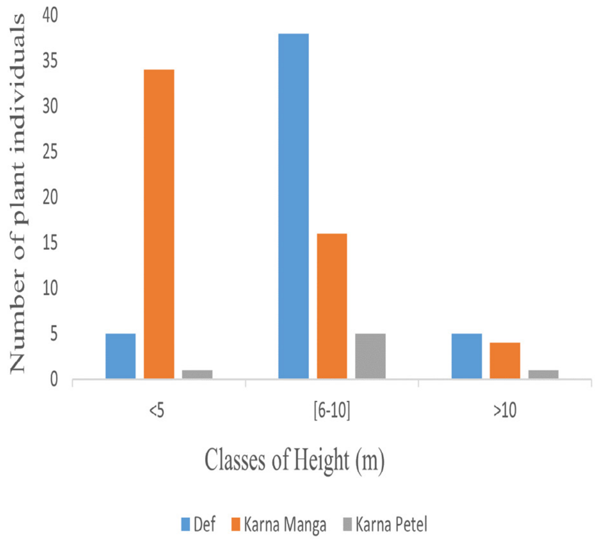

Figure 4: Structure of *D. microcarpum* according to height in the Mbe plain.

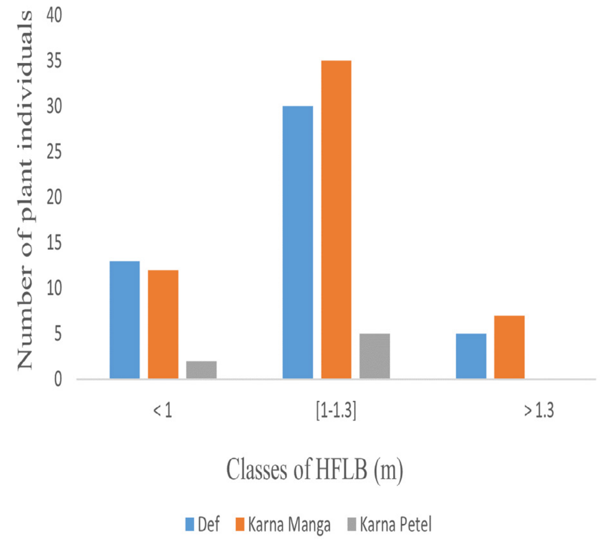

Figure 5: Structure of *D. microcarpum* according to HFLB in the Mbe plain.

was respectively 0% (in Sorobasso, no companion species), 3.55% (in Kalifabougou, co-occurring with *Daniellia oliveri*, *Piliostigma thonningii* and *Terminalia macroptera*), 5.58% (in Badogo co-occurring with *Daniellia oliveri*, *Isoberlinia doka,* and *Pterocarpus* sp.) and 10.41% (in Kodialan co-occurring with *Isoberlinia doka*, *Lannea acida,* and *Terminalia* sp.) (Kouyaté et al. 2020). This shows that the increasing frequency of the three main companion species *Bombax costatum*, *Piliostigma thonningii,* and *Terminalia macroptera* decreases regeneration of *D. microcarpum*. This would result in the low tree height of *D. microcarpum,* as found in this study. Competition for light between the plant and its three main co-occurring species would explain these results, especially in habitats such as shrubby forests and wooded savannas. In Ivory Coast, it has been reported that the species *Piliostigma thonningii* is an indicator of the presence of *D. microcarpum* on silty-clay soils (Fournier 1991). According to some authors, the topography and nature of the soil are factors determining the morphology of the *D. microcarpum* tree (Kouyaté 2002; Cavin 2007). For example, the tree tends to spread its crown and have a short shaft when it is in an open natural environment, i.e. when it does not have to compete for light with neighboring trees. Conversely, in forest galleries or in open forest, the tree tends to stretch out in search of light and to limit the development of its crown because it is hindered by contiguous tops. These results would make it possible, on an international level, to easily locate the species *D. microcarpum* based on the occurrence of these three species in ecosystems that are favourable to them. Consequently, the species *Bombax costatum*, *Piliostigma thonningii* and *Terminalia macroptera* would be indicators of the conservation of *D. microcarpum* in its areas of distribution, particularly in semi-arid and sub-Saharan areas.

Dendrometric characteristics of *D. microcarpum* population in the Mbe Plain

The results of DC analysis reflected an irregularity in the crown of *D. microcarpum* in the study area. Previously, irregularity of the plant crown had been reported (Berhault 1975). The mean height found in the study area is less than the 5-10 m reported by Kouyaté (2005). However, its mean height is higher than the 3.7 ± 0.3 m previously reported (Ouôba et al. 2005). According to Dresselhaus & Hückelhoven (2018) and Morrisa et al. (2020) abiotic, biotic, and human factors influence plant populations differently according to the environment. Ultimately, the results obtained in Table 3 could be explained by the fact that, in addition to abiotic factors (light, temperature, etc.) specific to the three localities (Def, Karna Petel, and Karna Manga), in Karna Manga the exchanges with the environment (absorption, photosynthesis, etc.) and the biotic factors (growth rate, diet, etc.) of *Detarium microcarpum* are particular. This peculiarity would explain the more important development of the DC, DBH, HFLB, and height of *D. microcarpum* in this locality, compared to the other two sites. Therefore, the conservation of *D. microcarpum* would be sustainable locally in Karna Manga.

Structures of space occupation by *D. microcarpum* stands

Regardless of the dendrometric parameter evaluated, the structure of *D. microcarpum* is unstable. These results are in agreement with those of Favrichon et al. (1998). Indeed, these authors reported that the diametric structure or distribution of stems by diameter classes carries information on the stability (equilibrium) of the individuals of a plant. These results show that *D. microcarpum* is locally in a poor state of conservation. However, the conservation of the plant can be improved in the locality of Karna Manga compared to the other two localities.

Diameter of the crown (DC)

The DC structure obtained reflects fluctuations of the plant over time in the study area. This could be explained by the result of natural dynamics or illegal cutting of the plant's wood. Consequently, the conservation of the plant is not locally assured although, the locality of Karna Manga is indicated to better conserve it *in situ*. To achieve a balanced structure of the plant individuals in the study area, continuous regeneration, field monitoring and conservation of the adult plant individuals in these fields are indispensable. Indeed, regeneration strategies through domestication techniques are essential for the maintenance of young individuals. Also, strategies for the protection of older individuals of the plant are recommended.

Tree height

The results related to tree height in the study area indicate that in Karna Manga the maintenance of young individuals of the plant is ensured while that of adults and old is not. This could be explained by the natural regeneration of the plant through the seeds and by illegal cutting of its adult and old individuals. This regeneration could also be due to the plant's rejections obtained after the passage of bush fires as explained by Kouyaté (2005). The difference in the localities of Def and Karna Petel, could be explained by the fact that being in a breeding area, during their passage, the cattle trample the seeds of the plant thus inhibiting their germinative power. The dormancy of the seeds could also explain the fact that the maintenance of the young individuals of the plant is not assured. According to Kouyaté (2005), the germination of *D. microcarpum* seeds often requires pre-treatment to lift the dormancy. In Mali, local people have developed a technique that consists of boiling the seeds of the plant for 7 minutes followed by soaking in warm water for 24 hours to lift the dormancy (Sanogo 2000). The illegal cutting of old trees for firewood would explain the scarcity of these trees in these localities. Consequently, the conservation of *D. microcarpum* is not sustainable in the study area, although it is recommended *in situ* in the locality of Karna Manga. However, in Mali, conservation of the plant has been reported (Kouyaté 2005). Indeed, the plant can be conserved for five years through its seeds, unlike many other forest species. Thus, for sustainable conservation of the plant locally, it would be indispensable to proceed with its domestication *ex situ*.

Height of the first large living branch (HFLB)

The HFLB results indicate that the branches of *D. microcarpum* individuals are accessible (not very high) to the local populations in the study area. Therefore, these populations will not use destructive techniques to harvest the fruits of the plant. These results are consistent with those reported by Kouyaté (2005). Thus, HFLB is an indicator of the conservation of *D. microcarpum* in the study area. Therefore, the HFLB of the plant should be assessed in its other areas of global distribution.

CONCLUSION

The comparison of regeneration indicators (habitat, population distribution, dendrometric characteristics, and structure) of *D. microcarpum* was conducted in three localities (Def, Karna Manga, and Karna Petel) of Adamawa, Cameroon to determine where the plant is most stable. Locally (study area), the conservation of *D. microcarpum* was more successful *in situ* at Karna Manga regardless of the regeneration indicators assessed. However, this conservation was not sustainable, due to illegal cutting, etc. For sustainable management of *Detarium microcarpum* in the study area, a program of conservation (through domestication) and enhancement is recommended. Moreover, the study revealed which indicators are the most relevant for predicting optimal habitats for *D. microcarpum*.

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