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BORASSUS AETHIOPUM Mart. AGROFORESTRY PARKLANDS AND CLIMATE CHANGE MITIGATION IN CAMEROON

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ABSTRACT

Agroforestry parklands belong to multistrata agroforestry systems frequent in tropical Africa. Understanding the structure and carbon storage of these land use systems can be a good step toward their sustainable management. The objective of the study was to assess the demography structure and appreciate the carbon stock of the parklands to gauge the farmer perceptions on climate change. A total of 300 farmers were interviewed in households, thus 100 per agro-ecological zone. In total, 126 ha areas were set in parklands of the three agro-ecological zones of Cameroon (Adamawa, North and Far North). The dendrometric parameters recorded were: diameter (dbh), height and crown diameter. The above and below ground biomass were determined using allometric equations. The results reveal that *B.aethiopum* parklands supply essential ecosystem services to local populations through informal economies. The species richness ranges from 8 in the Far North to 13 species in the Adamawa agro-ecological zones. The density is 18.94 stems/ha. The population structure of *B. aethiopum* is bell-shaped indepently of the agro-ecological zone. Farmer perceptions vary according to agro-ecological zone. Nevertheless the following manifestations of climate change were common for the agro-ecological zones : regular flood, destruction of houses and farms, dryness, delay of rainfall and agricultural calender upset. Local strategies among which, use of organic fertilizers, reduction of busfires, reafforestation and respect sacred environments were developed to mitigate climate change. The ecological and economic services of *B. aethiopum* parklands are 376.548 tC/ha and 2 165 151 CFA respectively. In addition to the usual socio-economic and environmental functions of *B.aethiopum* agroforestry parklands of Cameroon, this study showed their ecological importance in terms of carbon sequestration capacity and agrobiodiversity.

Keywords: *B. aethioum* agroforestry parklands, Cameroon, Climate changes, Ecological services, Economical value, Structure.

INTRODUCTION

Parklands belongs to multistorey agroforestry systems which structure the subsaharian Africa agrarian lanscape. They are among the most performant agroforestry systems in tropical Africa [1]. They are monospefic (dominated by one species) or multispecific (codominance of two or more species) depending on the engeniosity of farmers. The landscape of the septentrional part of Cameroon from the Guinean Savannah Highlands to the Sudano-Sahelian zone is dominated by Agroforestry Parklands as in West Africa. Their existence duty, structure and physionomy are connected to anthropic interventions [2,3]. Beside, these parklands are characterized by their diversity and multifonctionality influenced by non anthropic factors. Through furnishing goods and services, the deliberate maintenance of useful trees species in agrarian landscape is important for socio-economical development of local populations [4,5]. They play a major function not only in the satisfaction of paramount needs of populations, but as well as in the biodiversity conservation [6]. Traditional agroforestry has been widely promoted in the tropics as a natural resource management strategy that attempts to balance the goals of agricultural development with the conservation of biodiversity. Agroforestry systems have the advantage to allow farmers to increase their yields while at the same time protecting the environment [7].

The volume of literature on various aspects of agroforestry parklands is increasing in West Africa [2,3, 8,9-27] while in Central Africa, out of works realized in Cameroon [16,28,29], few data exist on this problematic. In addition, data related to relationship between parklands and climate change are scarce. To fill in these gaps, the present study focus on the demographic structure, ecological services and the economic value of the *Borassus aethiopum* parklands in the zone. Therefore, the purpose of the study was to assess the demography structure and carbon stock of the multistrata in view to gauge the farmer perceptions on climate change.

MATERIALS AND METHODS

Study site

The study was undertaken in the septentrional part of Cameroon including three agro-ecological zones named Adamawa, North and Far North. These areas correspond to Guinean Savannah Highlands, Sudanian and Sahelian agro-ecological zones. They differ roughly by their climate, demography and vegetation characteristics [30]. They are situated along a climatic gradient driving from Beka Modibo (Adamawa region) to Logone Birni (Extreme North) (Table 1).

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Table 1: Characteristics of the study sites

Zones / Geographical coordinates	Latitude (°C)	Longitude (°C)	Main ethnies groups	Climate	Rainfall (mm)
Adamawa (Beka Modibo)	6°541139N	14°263153E	Mbere, Mboum, Peulh, Dandi	Guinean	1400
North (Poli)	8°4768877N	13°2352778E	Dawago, Tchamba	Sudanian	1000
Far North (Logone Birni)	11°7680579N	15°0797731E	Kotoko, Kabaye, Massa	Sahelian	781

METHODOLOGY

The study was conducted in various phases : household interviews, floristic analysis and estimation of carbon stocks.

In each agro-ecological zone, semi - structural interviews were carried out with 300 farmers of which 100 per zone. Discussions with farmers were based on the structure of the production systems, biodiversity knowledge, climate change and indigenous strategies developed locally for the conservation of biodiversity, uses of indigenous tree species as well as socio-economic factors which affect their daily activities. In addition, the survey evalued the sensitivity of farmers on the impacts of climate change and the vulnerability of the local ecosystem. Similar approaches have been successfully used in Cameroon [31] and in Benin [6].

For the floristic phase of the study, a total survey area of 126 hectares of parklands were explorated, thus 42 ha per agro-ecological zone. Compass and GPS were used to establish transects of 50 m in length over 20 m in width and the community sampling units were established (20 sampling plots/ha). In each plots, plants were identified and floristic composition enumerated. The diameter of trees was measured at 1.30 m aboveground for trees and at 0.30 m for shrublets. The measures effectuated throughout each transect follow standard forestry methods[32]. Savannah was used as witness. Likewise, for measuring diameter at breast height (dbh) and height, instruments like dbh meter and Finnish Caliper and measuring tape were employed for all woody species. The basal area of each species was determined in addition to the crown diameter.

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To estimate biomass of different trees, non-destructive methods were used. Biomass of Arecaceae was determined through specific allometric formula developed by various authors [33,34] : Y= = 6.666 + 12.826 • ($HT^{0.5}$) • ln(HT). Others allometric equations adapted for the dry areas were used for the non Arecaceae species: (AGB) = ρ * exp(-0.667+1.784 ln(D)+0.207 (ln(D))2 – 0.0281 (ln(D))3) [35]. For the dead stand, dead felt wood and the below ground biomass, specific allometric equations were used [36,37,38].

DATA PROCESSING AND ANALYSIS

The conversion of kgeqC to kgeqCO_2 was made and the total CO_2 sequestered in the parklands determined. According to figures of Ecosystems Marketplace from 2009 to 2016 [39], the average transaction price was estimated at 10 USD/t CO_2. The conversion was used to estimate the ecological service value considering that one dollar is equal to 575 FCFA. For all the quantitative data, analyse of variance was performed and the programme used was Statgraphic plus 5. 0.

RESULTS

Parklands have functions and produce useful ressources for farmers. They participate to the improvement of the economy of the households and concur to poverty reduction. Farmers of the northern part of Cameroon have good knowledges on its importance. In each zone, the local name of parkland exists in traditional lexicon. Thus, it is locally known in :

-Adamawa agro-ecological : as «Salbere/Salakire» in Mbere vernacular ; «Gaba baira» in Mboum ; «Loukgoudou» in Foulani ; «Salike» in Dandi ;

-North agro-ecological : as «Dadongo» (Dawago) ;

-Far North agro-ecological : as «Delep / Goum» in Kotoko, «Sinera / Zar» in Massa, «Vouwai/Woura» in Mousgoum, «Kalya» in Kabaye. A diversity of names are given to this traditional agrofoestry system practised since millenium.

Parklands are land use systems in which perenial woods are deliberately conserved in association with crops and / or animals in a spatial scatered arragement and / where exist both ecological and economical interactions between trees and other components of the systems [9]. They harvest from parklands (Fig.1) various products which they consumed and commercialized to accommodate and adapt to climate changes.

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a

b

Figure 1: Physionomy of *B.aethiopum* parkland

Use of products from *B. aethiopum* Parklands

Parklands supply essential ecosystem services to Cameroon population through informal economies. All the parts of the species are used in different domains by the population : feeding, handicraft, pharmacopea, fodder, energy and soil fertility [26,40]. Commercialization of products from the species constitutes the main socio-economic activities in the area where it is exploited. The pulp of the fruit is consumed and commercialized by the population as well as the hypocotil axis (Fig.2) [40]. Wine is produced from the tree.

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a b

Figure 2: Fruits (a) and hypocotil (b) of *B. aethiopum*

Palms and trunks of the species are used for construction, bridges and animal watering tools. In addition palms are used to weave (looms, baskets, mats). The hypocotil axis are cooked and consumed as vegetable named locally in Fufulde «basi». The cooked hypocotil are commercialized in local market while uncooked one are selled in regional. In account of these products, farmers harvest also products from other tree species conserved in the exploitation such as *Adansonia digitata*, *Hyphaene thebaica*, *Haematostaphis barteri* whose fruit pulps are consumed and marketed. In some agro-ecological areas like Adamawa, farmers have introduced exotic species such as *Persea americana*, *Mangifera indica*, *Citrus* spp., etc. in their parklands. In addition, farmers (10.83%) of the Northern and Far Northern proclaim unanimously that during drought, parklands become excellent touristic site to take a rest and for shade.

Local perceptions of climate change and adaptation

In the septentrional part of Cameroon, the impacts on various projections on changes of temperatures and precipitations sound low compared to the pressure of human activities. The most important manifestations of climate changes recognized by farmers include floods, dryness, frequent dust, abundance of plant parasits, destruction of properties (houses, farms, animals),etc. Farmers of the Adamawa, North and Far North zones are awared of the variability of the climate in their regions. Farmer perceptions vary according to the agro-ecological zone. The majority of farmers (46%) mentionned that the years 1996, 2010 and 2015 were very rainy in Adamawa while those of the North (48%) quoted 1999, 2010 and 2015 as such (Fig.3). In the Far North, the situation was totally different because farmers recognition of the variability of the climate was low. Nevertheless a few of them recognize that rainfall was abundant in 2005 (6%), 2010

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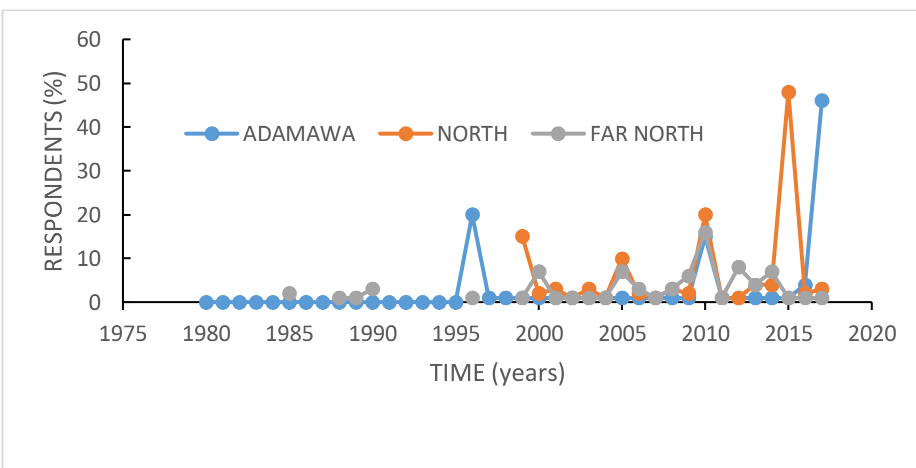
(16%) and 2012 (8%). Meanwhile, farmers (39,27%) of these three zones are unanimous on the fact that rainfall was very affluent in their areas in 2010. The climate changes in these zones went with frequent floods and violent winds. Fortunatelly, one of the contribution of the parklands was to reduce their rate. 60% of farmers of the three zones are unanimous on the fact that parklands improve the environment by increassing relative humidity and reducing the velocity of the wind. For the drought, 12.5% of respondents affirm that they improved it.

Concerning temperature, farmers of the Adamawa agro-ecological zone remembered the dryness of their environment in 2015 (14%), those of the North targeted years 2004 (15%), 2011(15%) and 2014 (36%) whereas those of the Far North named years 2006 (7%), 2007(7%), 2009 (5%) and 2011 (7%). During these periods of high temperature, life conditions became very difficult. The major risks of the climate changes according to the persons interviewed are flood, soil erosion and strong wind. For them, vegetation degradation of the parklands is a phenomenon which results from actual climatic dessication, repetitive drought and gradual climate aridity. They constitute the main reasons of species vulnerability. In some parklands, wind brake and often knock down trees.

The local strategies developed by farmers were : use of organic fertilizers, reduction of bush fires, reafforestation and respect of sacred groves. They think that the non respect of some traditional values among which sacred environments (sacred groves, social forbbiden, etc.) is one of the cause of climate change.



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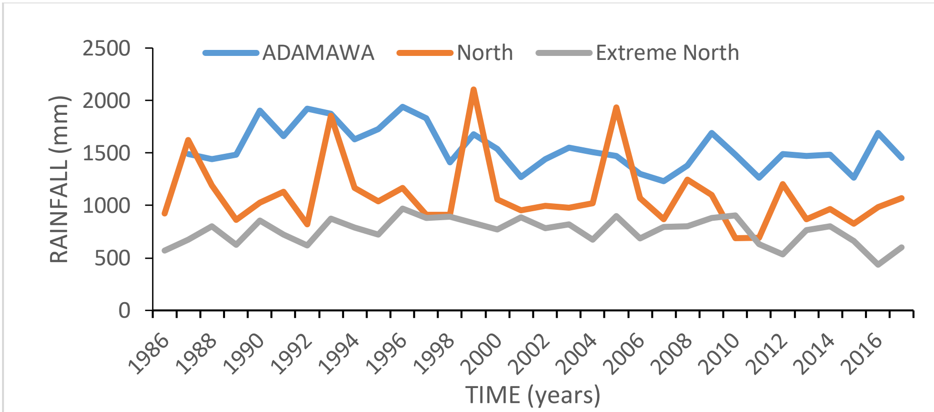

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Figure 3: Variability of rainfall from 1970 - 2019: according to farmers (a) and meteorolgical stations (b).

Borassus aethiopum parkland characteristics

B. aethiopum represents 80.84 % of trees in Adamawa, and 80% in North and Far North parklands respectively. The global percentage is 81.33% with a density of 18.94 stems/ha. The species richness ranges from 8 in the Far-North to 13 plant species in Adamawa parklands of Cameroon. The number of species decreases in parklands of Adamawa to Far North agro-ecological zones (Fig. 4) suggesting that farmers of the Adamawa agro-ecological zone conserve biodiversity and at the same time plant new species in their production systems. Parklands constitute a refuge of some important species. In the floristical view, Adamawa parklands differ from others by the presence of *Citrus* spp., *Persea americana* and *Psidium guajava* which were introduced by farmers. This situation suggests that farmers take care of their agrosystems.

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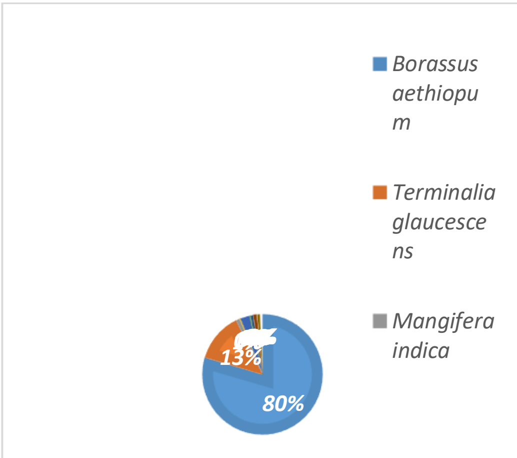
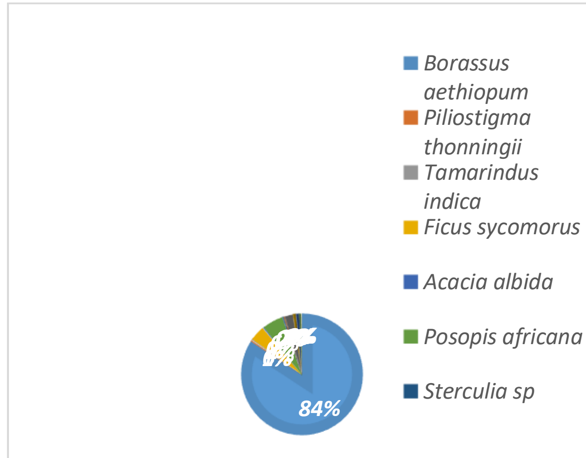
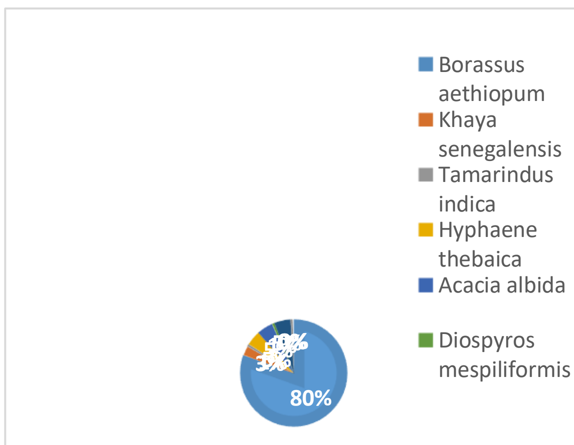


Adamawa



North

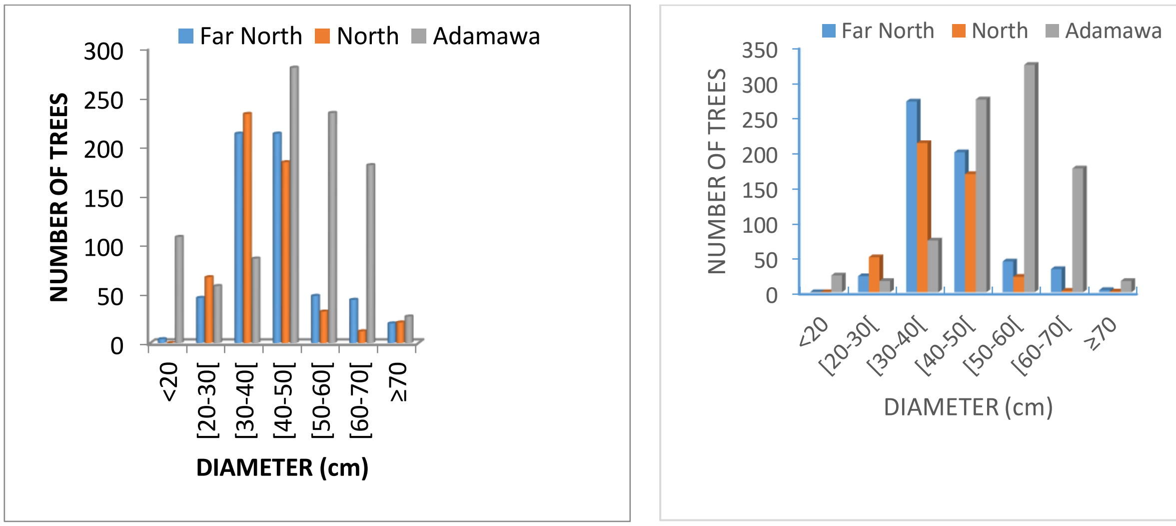


Far North

Figure 4: Floristic composition of *Borassus aethiopum* parklands in Cameroon

Demographic structure of *Borassus aethiopum* parklands in Cameroon

The global parkland structure varies according to agro-ecological zones. It is «J» distribution in Adamawa while for the two other zones, it is normal (bell). The «J» distribution shows that in the Adamawa parklands, there is a slight regeneration of the population of trees. The maximum of trees is found in the class diameter 30 - 70 cm (Fig. 5). This distribution suggests that old trees are maintained in the system while the regeneration of seedlings is difficult. Similar remarks were reported in *Borassus akeassi* parklands in Burkina Faso[21]. This indicates that farmers during clearing activities of their field protect seedlings (*B.aethiopum* and other species). Parklands of Far North and North zones present a normal distribution. This suggests that in these parklands, regeneration of trees and maintenance of old trees are difficult. Maximum of trees are located between 30-50 cm of diameter. The demography of *Borassus aethiopum* without other species exhibits a normal distribution independently of the agro - ecological zone (Fig. 5). As above mentionned, this distribution indicates that young and old plants in the system have difficulties to grow. These results agree those reported in *B.akeassi* in Benin[22].



a b

Figure 5: Parklands diametric distribution : global structure of parklands (a) and structure of *B. aethiopum* alone (b).

The height of *B.aethiopum* fluctuated between 5 and 20 m. The highest trees were found in the Far North agro-ecological zone confirming the trend observed when the global structure of parklands was considered (Fig.6ab). The maximum of trees (640) are located between 10-20 m class (Fig.6). This height confirms field observations on damages provoked by the wind on Borassus trees. In fact, many individuals were found destructed by wind in this agro-ecological zone.

The global canopy diameter structure of the parklands follows a «L» distribution with a maximum of trees concentrated below 5 m (Fig.6cd). This trend is respected when the structure of *B.aethiopum* is considered alone. The maximum of trees in the global structure comes from Adamawa and North agro-ecological zones whereas for the Far North the canopy of the trees dominanted in the 5-10 m class. Considering *B. aethiopum* alone, the North and Adamawa agro-ecological zones are dominant with a slight superiority in the North (Fig.6d).

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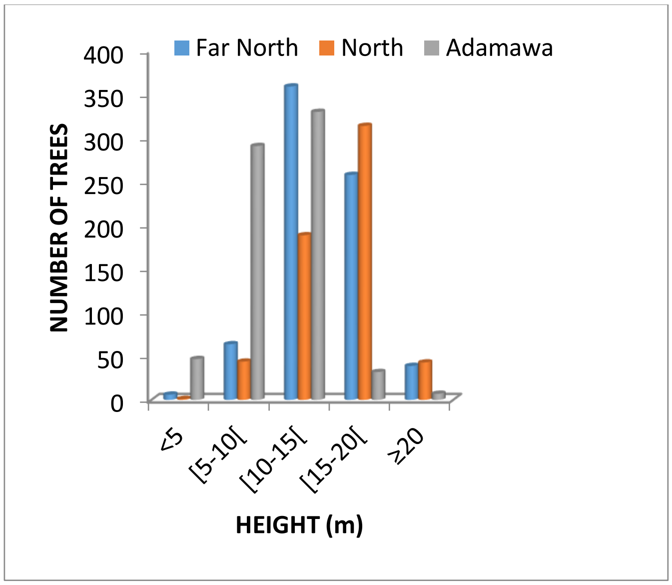

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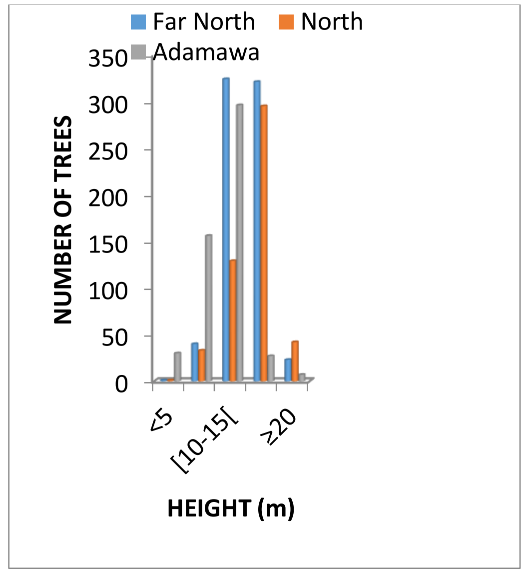

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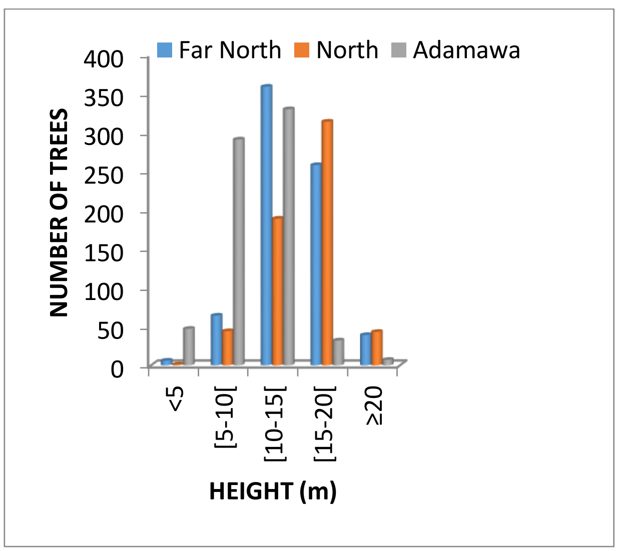
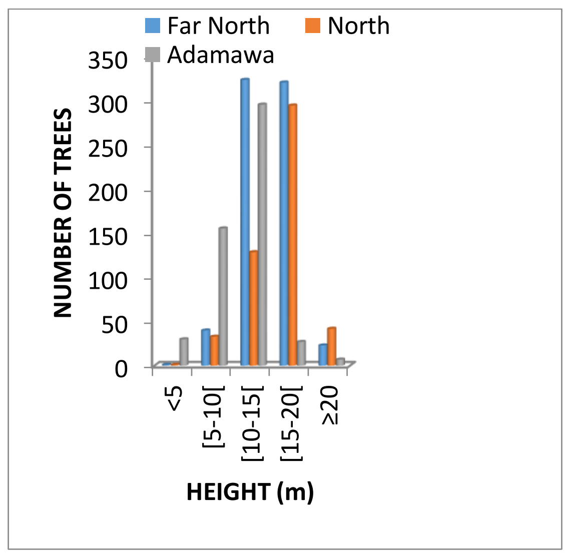


c



d

Figure 6: Distribution of the height and diameter of canopy of parklands : global structure of the system (a) and *B.aethiopum* alone (b), global diameter structure of canopy (c) and *B.aethiopum* alone (d).

Stratification of the parklands is roughly constituted by about three layers. The above ground layer (0-4m) is characterized by crops which composition varies according the zone : Far North (Logone Birni) (*Sorghum bicolor*, *Zea mays*, *Vigna inguiculata*, *Lypersicon esculentus*, vegetables, *Alium* spp., *Gossypium hirsutum*, *Arachis hypogaea*, *Oriza sativum* and *Phaseolus* *vulgaris*) ; North (Poli) (*Sorghum bicolor*, Zea mays, *Gossypium hirsutum*, *Arachis hypogaea*, *Oriza sativum*, *Phaseolus vulgaris*) and Adamawa (Beka modibo) (*Manihot esculenta*, *Phaseolus vulgaris*, *Zea mays*, *Cucumis* spp., *Dioscorea dumentorum*, *Arachis hypogaea*, *Ipomea batatas* and *Glycine max*).

The shrub layer (4-10m) is the most diversified stratum with *Acacia nilotica*, *Diospyros mespiliformis*, *Hyphaene thebaica*, *Piliostigma thonningii*, *Tamarindus indica*, *Terminalia glaucescens*, *Securidaca longepedunculata*, *Sterculia* sp., *Citrus* spp., *Psidium guajava*, etc.

The woody layer (≥10m) is composed of *Adansonia digitata*, *Albizia zygia*, *Bombax costatum*, *Borasus aethiopum*, *Haematostaphis barteri*, *Ficus sycomorus* and *Khaya senegalensis*. It can be mentioned that *Mangifera indica* and *Persea americana* are present only in the woody layer of the Adamawa agro-ecology. They were introduced by farmers because the climate is moderate compared to the dry area.

Ecological services and economical value of *Borassus aethiopum* parklands

The total carbon stock of 102.70 tC /ha was obtained in the *Borassus aethiopum* parklands. The main species, *B. aethiopum* accumulated 87.9t/ha itself representing 85.59 % of the carbon sequestrated. Among the different agro - ecological zones, Adamawa stocks 43.134±4.724tC/ha while the North is the last with 27.826±4.841tC/ha. However there is not a significant difference between parklands from different agro - ecological zones of Cameroon (0.066>0.05). This behaviour indicates that the potential of sequestration of *B. aethiopum* parklands is homogenous along the climatic gradient. However, the ecological services of the parklands varies from 102.386±1.800 tCO_2 in the North to 158.176±1.722 tCO_2 in Adamawa region (Tableau 2).

Table 2: Ecosystemic and economic services of parklands

		Adamawa	North	Far North	Total
Borassus aethiopum	Above ground	27.656±1.802	18.324±0.943	19.730±0.975	65.710±1.240
	Below ground	8.875±1.051	6.851±1.077	6.464±1.087	22.190±1.072
	Deadstand	0.234±0.071	0.364±0.072	0.188±0.072	0.786±0.072
Other species	Above ground	4.643±0.895	1.783±0.967	3.679±0.917	10.105±0.677
	Below	1.727±0.279	0.599±0.286	1.181±0.286	3.507±0.284

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	ground				
Total (tC /ha)		43.135±0.574	27.921±0.600	31.242±0.588	102.695±0.587
Ecological service (tCO_2/ha)		158.176±1.722	102.386±1.800	114.564±1.764	376.548
Economical value ($USA)		1581.76±1.722	1023.86±1.800	1145.64±1.764	3765.48 $
Economical value (CFFA)		909 512	588 719.5	658 743	2165 151 CFA

DISCUSSION

In the tropics, preservation of useful trees species in farmers lands remains a rule during clearing, hence the actual physionomy of the parklands draws its origin. Conservation and management of useful tree species in farms explains the actual floristic composition of agrosystems. In the same time, the proportion of tree species retained in the farms increases compared to the natural vegetation. *B. aethiopum* represents 81.33% of the number of species of the parklands. Whatever, the density of *B. aethiopum* is the most important. The structure of *B.aethiopum* disagrees that of *Parkia biglobosa* in Benin [18]. The ecology and the population density are the possible explanations of this situation. Compared to west african parklands, *B. aethiopum* parklands in Cameroon are less diversified [21]. During the agricultural intercampaign period, farmers make tacit agreement with herdmen to graze cattle in the parklands. It is a <<win win>> deed of which food for hersder and fertility for the farmer. The pastoral management of the parklands modifies the floristic composition and landscape [26]. The total specific richness of woody species recorded in parklands of Cameroon is comparable to that obtained in Nigeria (22 espèces) [41] and in Togo (25 espèces) [15]; but less than that of South of Burkina Faso (46 espèces) [13]. The density obtained is these parklands is similar to that in North West of Atacora (19 stems /ha) [42] and in northern Cameroon (14 - 47 stems/ha) [29]; but less than those recorded in Togo (32-82 stems/ha) [15]; in Benin (30-36 stems/ha) [27] and higher than those in land uses nexting cynegetic area of Pendjari (7.9 ± 5.4 stems/ha) [6]. The socio-economic importance of *B. aethiopum* induces a strong pressure on its population in Cameroon like elsewhere. These parklands present debated distributions showing their dynamism with a low renewal of woody population. The intense production of hypocotil is one of the possible explanations. Analogous « L » distribution was reported in *Parkia biglobosa* parklands in Doufelgou (Togo) [15]. Nevertheless, «J» distribution was reported in parklands of Bamou' bassin [27]. This distribution structure was characterized by a rising repartion of individuals from low to large diameters in *P. biglobosa* and *Vitellaria paradoxa* parklands. Gbesso *et al*.(2014) reported in the same species in Sudano-sahelian zone of Benin, a normal distribution[22]. Concerning the structure of the height of the species, it is normal with individual of high size. To ensure the conservation of the species, it is essential to assess how exploitation affects the population processes and overall population dynamics of the species.

Carbon stock, sequestration potential and economic value

Several works have shown the role of agroforestry systems as an opportunity to reduce CO_2 concentrations in the atmosphere by increasing carbon stocks in agricultural lands [43,44, 45, 46, 47]. Aboveground carbon only for *B.aethiopum* ranged from 6.851±1.077 to 8.875±1.051tC/ha. Belowground biomass ranged from 0.599±0.286 to 1.181±0.286 tC/ha. In terms of economic value, the total carbon stock in the three ecological zones of Cameroon is 3765.48 $ (2 165151 FCFA). Adamawa parklands have a very high economic value of 1581.76±1.72 $ (909 512F FCFA) versus 1023.86±1.80$ (588 719.5 FCFA) in those of the North. Despite certains phenomenons which destroy parklands, those of *B. aethiopum* are economically profitable and appear as an attractive alternative in terms of production of timber and the fight against global warming.

Climate change

Climate change is not perceived only by scientists, farmers are awared of it in their zones and have good knowledges on the variations of climate in their area in certains years through natural and physical factors such as yield decreasing or abundant precipitations, frequent floods, houses open to violent winds and dryness, erosion and sedimentation, appearance of new species, proliferation of plant parasites, rainfall delay and farm calender upset, etc. Very often, they think that profanation of sacred environments by the population is one the cause of climate changes. Some of their declarations are confirmed by meteorological data. In Adamawa zone, the years 2005, 2010 and 2016 were targeted as years of exceptional precipitations. Meteorological stations reveal that North, Far North and Adamawa, received 2105.5mm (1999) ; 903.9 mm (2010) and 1940 mm (1996) of water respectively. Concerning temperature, it fluctuated in 2015 from 20.62 to 32.49 °C whereas in 2016, it varies from 23.15 to 35.67°C. In the North in 2014, the minimum temperature is 22.66 while the maximum was 35.31°C. Finally, in the Far North in 2011, the mean temperature was 29.28°C.

Farmers are vulnerable to effects of climate change. In Africa, Cameroon is characterized by strong climate variations since 1960 [31]. The rise of pluviometry and temperature is palpable on annual, seasonal and monthly scales. The issue here is to bring out an analysis of the evolution of the climate in the septentrional zones of Cameroon from 1986 to 2018 in order to establish the bond between climatic changes and farmer declarations. The farmers declarations are confirmed by the climate data (pluviometry, temperature, etc.) obtained from meteorological stations of the three agro-ecological zones.

Borassus aethiopum species showed an important role in mitigating climate change; its sequestration potential represents 85.59% of the biomass stored in these parklands. Conservation of forests, including those under the control of local communities in developing countries, is an important component of a comprehensive climate mitigation strategy [48]. The present study identified *B.aethiopum* parklands of Cameroon as an important carbon sink due to the relative high diversity of plant species which significantly contribute to reduce atmospheric carbon. The quantity of carbon stock obtained during field investigation range between 27.826±4.841–43.134±4.724 $tC.ha^{-1}$, values generally found in semi-arid natural ecosystems [43,45, 49]. *B.aethiopum* the most represented species (≥ 80%) in these parklands in terms of individuals had been reported by several studies to have a good regeneration [6,25]. The protection of these parklands from bush fire could help to avoid their destruction and therefore improve their capacity to mitigate climate change. Farmers parceive climate changes through many natural and physical factors. Against these climate changes, they develop endogenous flexible strategies such as use of organic fertilizers, reafforestation, reduction of bushfires, respect of traditional culture, etc. These results suggest that the *B.aethiopum* agrosforestry parklands of Cameroon need to be taken into account in national environment protection policies as an alternative to respond to international agreements related to biodiversity conservation, combatting desertification and climate change as trade-off of safeguarding cultural heritage.

CONCLUSION

The current study highlights the key role of *B. aethiopum* parklands of Cameroon in addressing some environmental problems including biodiversity losses, climate changes and desertification. Out of the adoption of organic fertilizer, reafforestation and reduction of bushfires, no efficient endogenous and continuous measures of adaptation have been recorded. The extension of the dry season could affect the natural regeneration of the *B. aethiopum* parklands. In addition to the usual socio-economic and environmental functions of *B.aethiopum* parklands of Cameroon in terms of supply of food, wood and energy and reducing pressure on natural forests, this study showed their ecological importance in terms of carbon sequestration capacity and agrobiodiversity.

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