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Composition, Structure And Diversity of The Vegetation of The Manda National Park (MNP) in The Moyen-Chari Province of Chad

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Abstract

The present work was initiated in order to evaluate the composition, structure and diversity of the flora of the Manda National Park (MNP) to contribute to its sustainable management. The survey area is a square plot of 1m x 1m and a semi plot of 10m x 10m respectively for grassy savannah and shrub savannah and a rectangular plot of 50m x 20m for woodland and tree savannah. The diameter at breast height and total height of all woody individuals were measured. The floristic inventory resulted in a total of 12885 individuals belonging to 102 species, 81 genera and 34 families. The tree savannah (78 species, 59 genera and 26 families) and woodland (65 species, 54 genera and 24 families) are richer in taxonomic groups than the shrub savannah (38 species, 32 genera and 16 families) and the grassy savannah (19 species, 18 genera and 8 families) The average density of the park and its Shannon index are respectively 1956 ind/ha and 2.82 bits. For these plant formations, their density and Shannon index are highest in the tree savannah

(3507 ind/ha and 3.11 bits) and lowest in the shrub savannah (1133 ind/ha and 2.03 bits). The Piélou index for each of the plant formations is low (0.19 to 0.25), indicating a poor equi- distribution of individuals between the different species for the plant formations. In the woodland, the diametrical and vertical distributions are bell-shaped and skewed to the right, centered on young individuals. In contrast, in the Tree and Shrub Savannahs the distributions are in the shape of an inverted "J", characteristic of a formation dominated by juvenile individuals. These results lead to the conclusion that the Manda Park has a good species diversity and is under anthropic pressure due to the destruction of its vegetation cover.

Keywords: Composition, Structure, Diversity, Vegetation, MNP, Moyen-Chari, Chad

Introduction

Tropical forests are the richest in biological diversity, but they are the most threatened by anthropogenic activities due largely to population growth (Ajavon *et al*., 2019). The characterization of the forest structure of tropical forests is a major issue for the management of natural forests, is also one of the most important sources of basic data especially for research on biological diversity, development of forest management systems, management and nature conservation (Masharabu, 2010; Ndotam *et al*., 2017). Knowledge of forest attributes appears necessary to better understand the level of threat and propose sustainable management strategies (Aboubacar *et al*., 2018). At a large scale, forest attributes vary with climate and geomorphology (Paget, 1999; Steege *et al*., 2006; Grégoire *et al*., 2010). Thus, sustainable forest management and biodiversity conservation require monitoring of the condition of forest formations through effective methods of structural vegetation analysis (Guynn *et al*. 2004; Leblanc 2014; Sandjong, 2018). Biodiversity conservation is a cornerstone of sustainable forest management and a key factor in maintaining forest ecosystem functioning (FAO, 2011). Chad is considered one of the most biologically diverse countries in the Sahelo-Saharan regions (Doumenge *et al*., 2015) and hosts a rich and highly diverse flora (Anonymous, 2014). However, this threatened national biodiversity is poorly documented and not well known (Doumenge *et al*., 2015). According to various sources of available information, it is estimated that there are about 4318 wild and domesticated higher plant species, including 71 endemic species including *Ficus carica, Ficus salicifolia, Rauwolfia sp, Adina microcephala, Clematis tibestica, Celsia tibestica, Artemisia tilhona* (endemic to Tibesti), etc. and 11 threatened species including *Anogeissus leiocarpus, Pteropcarpus enrinaceus, Vitex doniana, Detarium microcarpum, Prosopis africana*, etc (Anonymous, 2014). Thiombiano *et al* (2016) rightly

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remind us that forest inventories are unavoidable in sustainable wood resource management policies. One cannot then claim to do nature reserve management without knowing the structure, dynamics and functioning of phytocenoses (Ndotam *et al*., 2017). The conservation of biological diversity contributes decisively to limiting the magnitude of climate change and reducing its harmful effects by making ecosystems and consequently human societies more resilient (Anonymous, 2014). Classically forest structure parameters are obtained by aggregating individual dendrometric measurements such as diameter, height, etc. (Hall *et al*., 1998; Gregoire *et al*., 2010). Increasing forest potential and conserving biodiversity has become a key concern of sustainable development in recent years. This awareness has grown out of bitter observations about the rate of decline of forest resources at the local, continental and global levels (Mertens *et al*., 2019). However, biodiversity is still very rich, and many flagship species are present in the parks. However, the level of classification and protection of the various protected areas is not always sufficient to ensure their long-term protection (IUCN/PACO, 2008). This is the case of the Manda National Park, which suffers from pastoral pressure, poaching, illegal fishing due to demographic pressure, etc. Given the seriousness of the ecological situation in the Manda National Park, the need for an action plan for the conservation and preservation of biodiversity is imperative in order to curb the degradation of biological resources. It is in this respect that the interest of our work lies, which aims to analyze the current state of the MNP in order to provide attributes of management and improvement adapted to current conditions. More specifically, it will be a question of determining the composition, structure and floristic diversity of this park.

1- Material and methods

2- 2-1 Study site

The study sites are located in the Manda National Park (MNP), which is 25 km northwest of Sarh, capital of the Barh-Kôh Department, Moyen-Chari Province (Figure 1). It is located between 9°20' and 9°35' North latitude and 17°45' and 18°20' East longitude and at an altitude ranging from 344 to 691 m. The area is characterized by a tropical climate, with an average annual rainfall of 1061.41 mm, an average annual temperature of 24.5°C, and a relative humidity depending on the month of 32 to 85% (ASECNA, 2018).The MNP was created in 1951 as a regional wildlife reserve, as was the Derby Elk (Taurotragus derbianus) which characterises it. In 1965, the 108,000 ha wildlife reserve became a National Park by Decree No. 243/PR/EFPC/PNR of 23 October 1967, which increased its area to 114,000 ha. According to the latest IUCN classification, the PNM belongs to category II (PAPNM, 2010).

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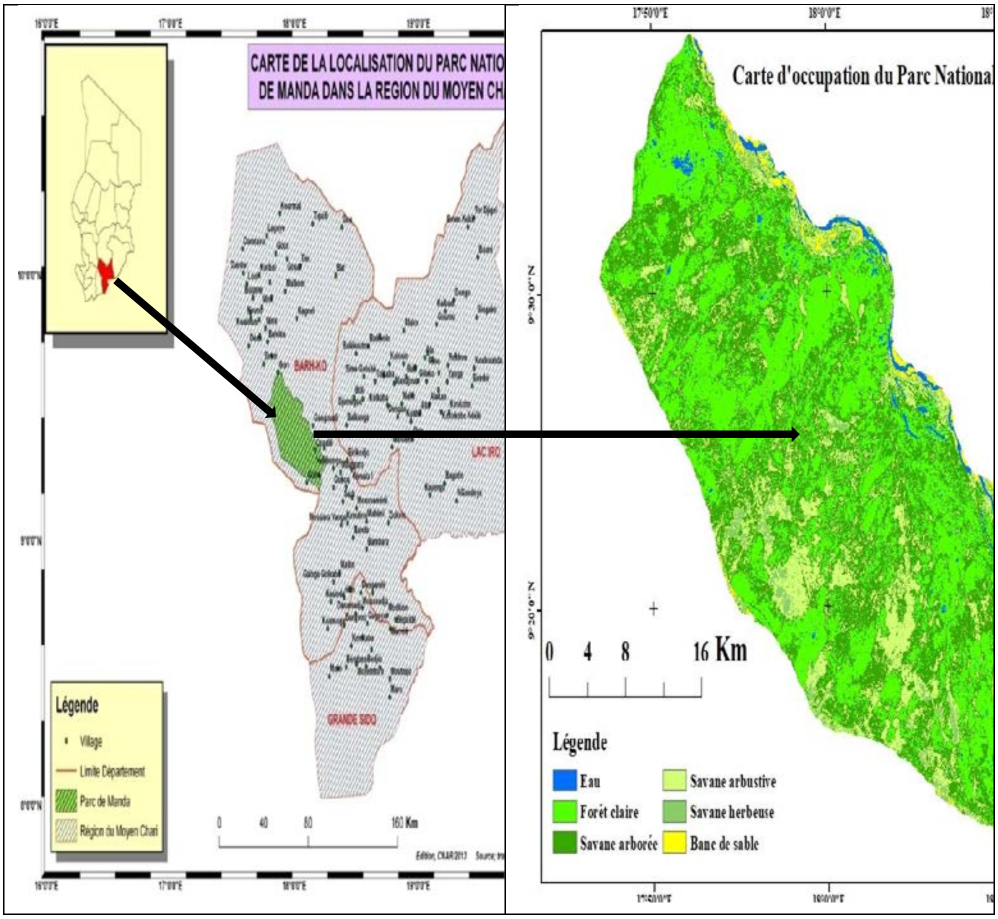

Figure 1: Location of the MNP in the Moyen-Chari region of Chad. (Source: Esaie Waya, 2019)

The soils are varied and the main types are: Erosion soils on acidic rocks that are dominant on Mount Niellim; sesquioxides with ferruginous stains and concretions and cuirasses that occur on lateritic slabs in the Niellim zone; vertisols in certain flood zones between Koutou and Niellim; Ferralitic soils that are widely exposed in the Koutou and Djoli zones; tropical ferruginous soils in the center of the park, from Nguéré to Koutou; and hydromorphic soils characteristic of soils in the south of the park (Pias, 1964). The MNP is served by a hydrographic network, in its eastern part by the Chari River and in the south by the Barh Sara. Two of the three main tributaries of the Chari have their confluences in the MNP: the Bahr Sara and the Bahr Salamat. In addition, 13 temporary and 23 permanent pools have been identified in the park (Tchago, 1999). The vegetation formations are gallery forests, shrub and tree savannahs. On the whole, the vegetation is of the Sudanian type, the density and distribution of which are a function of the topography and the nature of the soil. Outside the plain, clear forest and wooded savannah with dominant

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legumes alternate with patches of dry forest or riparian forest (Pias, 1970). The diversity of wildlife is underestimated. Only vertebrates are moderately studied, with about ten wild families reported by IUCN/PACO (2008). The riparian populations of the MNP are estimated at 85592 inhabitants (Saradoum, 2012) and they are largely farmers, but there are increasing numbers of fishermen and pastoralists. They belong to the large Sara ethnic group, the majority in the southern part of Chad.

2-2 Floristic inventory

Data collection was carried out in the dry season because of the ease of access to the site, for five (05) months, from November 12, 2019 to March 14, 2020. The inventory is therefore quasi-synchronous, because the duration of the study is not likely to cause deep variations in the vegetation, except the occurrence of an unpredictable disturbing event.

The method chosen for the floristic inventories was that of variable area sampling. The size of the surveys was determined by taking into account the work done in tropical environments by several authors (Sinsin, 1993; Oumorou, 2003; Djego, 2006; Toko, 2008; Arouna, 2012) who used areas varying between 1 and 1000 m² depending on the vegetation types. In the case of our study, the survey area is a square plot of 1 m² (1m x 1m) and a square sub-plot of 100 m² (10m x 10m) respectively for grassy savanna and shrub savanna and a rectangular plot of 1000 m² (50m x 20m) for tree savanna and woodland. The number of replicates varies according to the surface area of the vegetation types and their floristic homogeneity and the topography of the stations. In total, 148 plots were inventoried, divided into 20 plots for the grassy savannah, 28 sub-plots for the shrubby savannah, and 46 and 54 plots for the tree savannah and woodland respectively.

All woody species were identified and their local and scientific names were recorded. For those not identified in the field, specimens were collected and compared to existing floras (Flore illustrée du Tchad, 2019; Adventrop, 1995; Arbonnier, 2009; ligneux du sahel, 2008).

During the inventory, the diameter at breast height (DBH= 1.30 m) of all individuals was measured with a tape measure and their height was determined using the 7 m long graduated pole or Blum-Leiss.

2-3 Analysis and statistical processing of data

2-3-1 Species richness (R)

This is the number of plant species recorded per plot. This indicator is not sufficient to measure specific diversity because it does not allow differentiating between groups that have the same number of species but different numbers.

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2-3-2 Shannon diversity index (H')

The diversity index expresses the diversity of species within plant groups. It is calculated from the following formula:

$$H' = -\sum_{i=1}^{n} Pilog2Pi$$

Where Pi =ni/N; ni = number of individuals of species i; N = total number of individuals,

log2: Logarithm of base two (02), i ranging from 1 to S (total number of species).

H' usually ranges from 0 to 5 and is expressed in bits. It measures the dominance of the community by a few species, and is low when there is dominance. The Shannon index is minimal (H' = 0) if all the individuals in the stand belong to the same species. H' is maximum when all individuals are equally distributed across all species (Miderho *et al*., 2017; Wanie, 2020) and corresponds to environmental conditions that are favorable for the settlement of many species; this is a sign of high environmental stability (Dajoz, 1985; Ajavon *et al*., 2019). According to Arouna (2012) and Ajavon *et al*. (2019), the threshold for assessing the Shannon index is as follows:

- If $0 \leq H' < 2$ bits, floral biodiversity is low;
- If $2 \leq H' < 2.5$ bits, floristic biodiversity is medium;
- If $H' \geq 2.5$ bit, floristic biodiversity is high.

2-3-3 Pielou's equitability (E)

Pielou's equitability or evenness is a measure of the degree of diversity achieved by the stand and corresponds to the ratio between the effective diversity (H') and the theoretical maximum diversity (Hmax) which is equal to the base 2 log of the number of taxa (Oumorou, 2003; Arouna, 2012). It is thus determined from the following formula:

$$E = H'/\log 2R$$

H': represents the Shannon diversity index;

$Hmax$ = log2R: the theoretical value of the maximum diversity achievable in each formation.

Equitability varies between 0 and 1. It tends to 0 if nearly all the numbers correspond to a single species in the stand and tends to 1 when each species is nearly represented by the same number of individuals or the same cover. High Pielou equitability may then be a sign of a balanced stand (Dajoz, 1985; Ajavon *et al*., 2019). The threshold for assessing Pielou equitability:

$0 \leq E < 0.5$, low diversity;

$0.5 \leq E < 0.7$, medium diversity;

$E \geq 0.7$, strong diversity.

2-3-4 Simpson's index (1-D)

The Simpson index measures the probability that two randomly selected individuals belonging to the same species. It is given by the formula:

$$1 - D = \sum_{i=1}^{S} Pi^2,$$

Where Pi =ni/N; ni = number of individuals of species i; N = total number of individuals,

This index will have a value of 0 to indicate maximum diversity and a value of 1 to indicate minimum diversity. For the purpose of obtaining "more intuitive" values, Simpson's diversity index represented by (1-*D*) may be preferred; with the maximum diversity represented by the value 1, and the minimum diversity by the value 0 (Bütler, 2000; Ajavon *et al*., 2019). Note that this index gives more weight to abundant species than to rare species. Adding rare species to a sample, hardly changes the value of Simpson's diversity index (Ajavon *et al*., 2019).

2-3-5 Jaccard's coefficient of floristic similarity

It is used to compare different collection units and assess the diversity β. It is given by the formula:

$$PJ = \frac{c}{a+b-c} \times 100;$$

Where a = number of species in list a; b = number of species in list b; c = number of species common to lists a and b. The similarity between habitats is expressed by the high value of this index.

2-3-6 The Hamming distance

This is proposed by Daget *et al*. (2003) and is added to PJ to compare floristic surveys according to the formula:

$$H = 100\text{-}PJ$$

where PJ is the Jaccard index. The thresholds used are shown in Table 1.

Table 1: Thresholds for comparison of floristic surveys according to Hamming distance

Thresholds	Comparison
$H \leq 20$	Very small floristic difference
$20 < H < 40$	Low floristic difference
$40 < H < 60$	Floristic difference medium
$60 < H < 80$	Floristic difference strong
$80 < H$	Floristic difference very strong

2-3-7 Diameter structure

The distribution of diameter classes is another important indicator involved in the structural study of vegetation, its evolutionary trend and regeneration dynamics (Sandjong, 2018). Diameter structures are indicative of

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stand life events (Rondeux, 1999; Arouna, 2012). Diameter structures are generally histograms constructed from the relative frequencies of equal magnitude diameter classes. Plants were grouped into four (04) diameter classes of 10cm interval 1=] 0 - 10], 2=] 10 - 20], 3=] 20 - 30], 4=] 30 and +∞].

2-3-8 Vertical structure

The description of the vertical structure of the ecosystem was done based on the parameters such as height classes. The histogram of the height distribution gives an idea about the vertical structure of the studied formation (vegetation profile). The values are grouped in intervals of 3 m. The classes of heights in meters of the same amplitude in the majority, restore a certain equity in the vertical stratification of the individuals. Five (05) height classes are retained and are as follows: 1=]3-6], 2=]6-9], 3=]9-12], 4=]12-15], 5=]15 and +∞].

Composition, taxonomic structure, and diversity index were calculated using Microsoft Excel 2010 software and XLSTAT 2016 software was used for linear regressions between diameter and height.

3-Results

3-1 Specific composition of the MNP

The floristic inventory of the study area identified a total of 12,885 individuals belonging to 102 species (83 woody species and 19 herbaceous species), 81 genera (63 and 18 woody and herbaceous genera respectively) and 34 families, including 26 families for woody species and 8 families for herbaceous species (Table 2). Tree savanna (78 species, 59 genera and 26 families) and woodland (65 species, 54 genera and 24 families) are richer in species, genera and family than shrub savanna (38 species, 32 genera and 16 families) and grassy savanna (19 species, 18 genera and 8 families).

The most abundant species are *Anogeissus leiocarpa* (28.24%) in the woodland, *Detarium microcarpum* (21.28 and 22.30%) respectively in the tree savannah and shrub savannah, *spermacoce chaetocephala* (13.56%) in the grassy savannah. The most represented families are Fabaceae (24 species), Combretaceae (10 species), Poaceae (9 species), Rubiaceae and Malvaceae with 8 species each. Those common to all four vegetation types studied are Fabaceae, Malvaceae and Rubiaceae. The highest number of genera per family is recorded in Fabaceae (22 genera) and Poaceae (8 genera).

Table 2: Number of individuals and taxa in the four vegetation types

Taxa	FC	SA	SU	SH	Total
Individuals	6627	5217	982	59	**12885**
Species	65	78	38	19	**102**
Genera	54	59	32	18	**81**
Families	26	27	16	8	**34**

woodland (**FC**), Tree savannah (**SA**), Shrubby Savannah(**SU**), Grassy Savannah (**SH**)

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3-2 Density

The average density of the park is 1956 individuals per hectare, including 1227 individuals per hectare for the woodland, 1133 individuals per hectare for the tree savannah and 3507 individuals per hectare for the shrubby savannah (Figure 2). The shrub savanna is the most dense in composition, followed by the woodland and the shrub savanna.

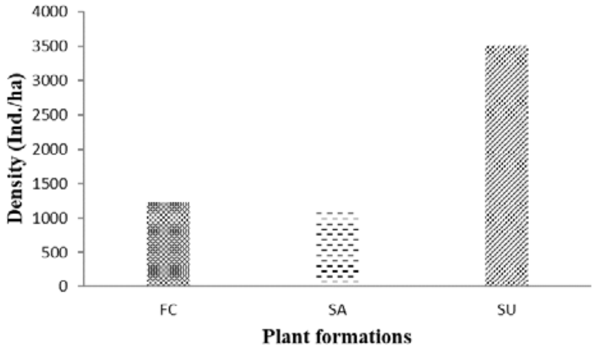

Figure 2: Density of woody plants in the three vegetation formations of the MNP. Woodland (FC), Tree savanna (SA) and Shrub savanna (SU).

3-3 Basal area

The basal area of the entire stand in the study area is 373.26 m²/ha and varies from 79.23 to 196.37 m²/ha for shrub savanna and woodland respectively (Figure 3 and Table 3). woodland dominates in terms of basal area, followed by shrub savanna and finally shrub savanna.

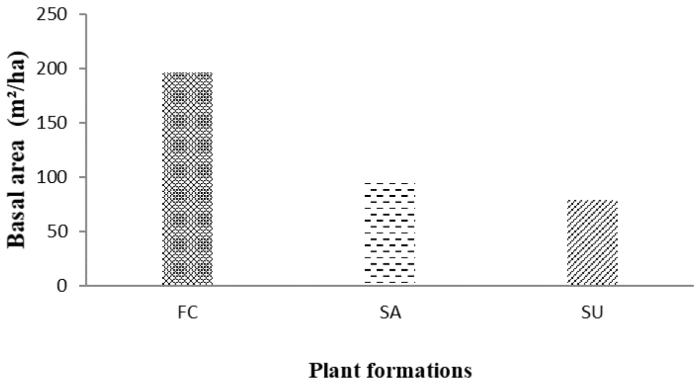

Figure 3: Basal area of the different vegetation types of the MNP

This basal area varies between species and according to the vegetation types (Table 3). Indeed, the most dominant species in the MNP is *Anogeissus leiocarpa* (75.77%) followed by *Guiera senegalensis* (29.41%), *Catunargam nilotica* (2879%) and *Detarium microcarpum* (26.22%). The least represented

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species in the MNP are *Erythrina sigmoidea* and *Maytenus senegalensis* with 0.01% each. Between vegetation types, the most represented species are *Anogeissus leiocarpa* (58.76%) and *Guiera senegalensis* (29.38%) in the woodland, *Anogeissus leiocarpa* (13.17%), *Detarium microcarpum* (11.08%) and *Pseudocedrela kotschyi* (11.84%) in the tree savannah, and *Catunargam nilotica* (2879%) in the shrubby savannah. On the other hand, the species least represented in each of the three vegetation types are *Catunargam nilotica* (0.01%), *Gardenia aqualla* (0.01%) and *Gardenia ternifolia* (0.01%) in the woodland, *Maytenus senegalensis* (0.01%), *Moringa oleifera* (0.01%) and *Ziziphus mucronata* (0.01%) in the tree savanna and finally *Pterocarpus lucens* (0.02%) and *Trema orientalis* (0.02%) in the shrub savanna.

Table 3: Specific and total basal area (m²/ha) in the three vegetation types of the MNP.

Species	FC	SA	SU	TOTAL	Species	FC	SA	SU	TOTAL
Acacia polyacantha	0,02	0,23	0,00	**0,25**	Isoberlinia doka	0,00	0,33	0,00	**0,33**
Acacia sieberiana	0,99	0,32	0,00	**1,31**	Khaya senegalensis	6,99	0,57	0,00	**7,57**
Afzelia africana	0,32	0,38	1,12	**1,83**	Lannea acida	1,23	1,21	0,00	**2,44**
Albizia adianthifolia	0,42	0,00	0,00	**0,42**	Lannea schimperi	0,00	0,13	0,00	**0,13**
Allophylus africanus	0,26	0,02	0,00	**0,28**	Lonchocarpus laxiflora	0,00	0,05	0,00	**0,05**
Ambligonocarpus andongensis	0,48	0,16	0,00	**0,64**	Maytenus senegalensis	0,00	0,01	0,00	**0,01**
Annona senegalensis	0,32	0,03	0,00	**0,35**	Mitragyna inermis	0,96	0,05	0,00	**1,00**
Anogeissus leiocarpus	58,76	13,17	3,85	**75,77**	Moringa oleifera	0,01	0,01	0,00	**0,02**
Azadirachta indica	0,02	0,00	0,00	**0,02**	Parinari curatellifolia	2,06	1,19	0,50	**3,76**
Balanites aegyptiaca	0,15	0,08	0,00	**0,23**	Parkia biglobosa	0,44	1,19	0,00	**1,63**
Bombax costatum	0,63	0,17	0,00	**0,80**	Pericopsis laxiflora	1,85	0,73	0,28	**2,86**
Bridelia ferruginea	0,27	0,53	0,28	**1,09**	Piliostigma reticulatum	0,00	3,80	0,00	**3,80**
Burkea africana	1,12	2,91	0,85	**4,88**	Piliostigma thonningii	1,80	0,89	0,15	**2,84**
Carissa edulis	0,00	0,03	0,00	**0,03**	Prosopis africana	13,83	0,72	1,06	**15,60**
Cassia sieberiana	7,07	1,05	0,00	**8,11**	Pseudocedrela kotschyi	1,08	11,84	0,00	**12,91**
Catunargam nilotica	0,01	0,04	28,74	**28,79**	Pterocarpus lucens	11,51	0,40	0,02	**11,93**
Ceiba pantandra	0,00	0,04	0,00	**0,04**	Saba senegalensis	0,44	0,40	0,73	**1,58**
Celtis integrifolia	0,07	0,00	0,00	**0,07**	Sarcocephalus latifolius	0,39	0,29	0,55	**1,23**
Combretum collinum	2,59	2,09	3,52	**8,21**	Sclerocarya birrea	0,88	0,21	0,00	**1,09**
Combretum glutinosum	2,01	1,09	1,15	**4,25**	Securidaca longipedunculata	0,05	0,31	0,06	**0,42**
Combretum molle	0,70	0,57	0,09	**1,37**	Senna siamea	0,00	0,21	0,00	**0,21**
Combretum nigricans	0,00	0,10	0,00	**0,10**	Sida rhombifolia	0,00	0,10	0,00	**0,10**
Commiphora pedunculata	0,09	0,00	0,00	**0,09**	Sterculia setigera	6,02	3,95	4,20	**14,17**
Crossopteryx febrifuga	2,69	4,55	1,19	**8,43**	Stereospermum kunthianum	1,56	2,47	0,41	**4,44**
Daniellia oliveri	5,68	4,40	0,00	**10,09**	Strychnos innocua	0,04	0,11	0,81	**0,96**
Detarium microcarpum	4,41	11,08	10,72	**26,22**	Strychnos spinosa	0,52	0,96	2,71	**4,18**
Dichrostachys cinerea	0,00	0,00	0,00	**0,00**	Swartzia madagascariensis	0,08	0,38	0,80	**1,25**
Diospyros mespiliformis	0,46	0,11	0,00	**0,57**	Tamarindus indica	3,61	1,06	0,32	**4,99**
Entada africana	0,00	0,13	0,31	**0,44**	Terminalia avicennioides	0,00	0,04	0,00	**0,04**
Erythrina sigmoidea	0,00	0,00	0,00	**0,01**	Terminalia glaucescens	3,58	2,27	0,33	**6,19**
Ficus capensis	0,00	0,03	0,00	**0,03**	Terminalia laxiflora	8,12	7,66	2,84	**18,62**
Ficus dekdekena	0,00	0,02	0,00	**0,02**	Terminalia macroptera	0,00	0,48	0,00	**0,48**
Ficus glumosa	0,00	2,10	0,00	**2,10**	Trema orientalis	0,20	0,15	0,02	**0,36**
Ficus platyphylla	0,93	1,79	0,00	**2,71**	Vitellaria paradoxa	1,19	3,80	0,26	**5,24**
Ficus sycomorus	0,03	0,07	0,00	**0,10**	Vitex doniana	0,11	0,10	0,00	**0,21**
Gardenia aqualla	0,01	0,08	0,00	**0,08**	Vitex simplicifolia	0,56	0,13	0,37	**1,06**
Gardenia erubescens	0,01	0,08	0,53	**0,62**	Ximenia americana	0,03	0,13	0,16	**0,32**
Gardenia ternifolia	0,00	0,13	1,64	**1,77**	Ziziphus abyssinica	0,04	0,14	0,20	**0,37**
Grewia flavescens	0,17	0,01	0,05	**0,23**	Ziziphus mucronata	0,08	0,01	0,00	**0,09**
Grewia venusta	0,00	0,73	6,21	**6,94**	**TATAL**	**196,37**	**97,65**	**79,23**	**373,26**
Guiera senegalensis	29,38	0,03	0,00	**29,41**					

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Hexalobus monopetalus	0,05	0,50	0,75	**1,30**
Hymenocardia acida	6,99	0,22	1,42	**8,63**
Hyphaena thebaica	0,00	0,14	0,00	**0,14**

woodland (**FC**), Tree savannah (**SA**), Shrubby Savannah (**SU**)

3-4 Diversity index, floristic equitability and similarity

Species richness, diversity index (Shannon and Simpson), and Piélou's evenness vary among the three vegetation types of the MNP (Table 4). Species richness decreases from woodland (6627) to shrub savanna (982) to tree savanna (5217). Shannon's index, simpson's index, and Piélou's evenness are highest in tree savanna (3.11 bits, 0.25, and 0.81), lowest in shrub savanna (2.03 bits, 0.20, and 0.68), and intermediate in woodland (2.52 bits, 0.19, and 0.73). Piélou's evenness for each of the three vegetation types is low, as the values for all three vegetation types are less than 0.5. With respect to Simpson's index, the values obtained are approximately equal to 1 (1-D≈1) in all three vegetation types.

Table 4: Different floristic index by vegetation types,

Index	FC	SA	SU
R	6627	5217	982
H'	2,52	3,11	2,03
E	0,19	0,25	0,20
1-D	0,73	0,81	0,68

H': Shannon Index**; E**: Piélou evenness; **1-D**: Simpson Index**; R**: Specificity Richness, **FC**: woodland, **SA**: Tree Savanna and **SU**: Shrub Savanna.

3-5 Similarity among the park's plant groupings

Table 5 presents the degree of similarity between the three vegetation types in Manda National Park through Jaccard's index (J) and Hamming's distance (H). The closer the Jaccard index value is to 100, the higher the similarity of the vegetation types. Whereas for Hamming, the higher the distance value, the less similarity the vegetation types show. The jaccard index tends towards 100% (70.23%) and the Hamming distance is low (29.76%) between the woodland and the tree savannah, indicating that the floristic difference is low between these two vegetation types of the MNP. On the other hand, between the woodland and the shrub savanna and between the shrub savanna and the tree savanna the jaccard index are average respectively 56.06% and 45% and the Hamming distance are also average, respectively 43.93% and 55%. This indicates that the floristic differences of these vegetation types of the MNP are average.

Table 5: Jaccard's index (J) and Hamming's distance (H) between the three vegetation formations of the MNP.

Index	FC-SA	FC-SU	SA-SU
J (%)	70.23	56.06	45
H (%)	29.76	43.93	55

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Floristic difference	**low**	**medium**	**medium**

woodland (**FC**), Tree savanna (**SA**) and shrubby savanna (**SU**).

3-6 Distribution of diameter classes

Figures 4 and 5 provide information on the floristic evolutionary trends of Manda National Park, in general, and its three vegetation formations in particular. The distribution of diameter classes is L-shaped (or inverted J-shaped) for the entire vegetation of the park (Figures 4), indicating that the number of individuals is higher for the small diameter classes (0-10 cm) than for the large classes (≥ 30 cm). That is, the number of individuals decreases with increasing diameter. This suggests that the regeneration of this park is good overall.

Between the three vegetation formations, the distribution of diameter classes is of the asymmetrical bell shape to the right, centered on 10-20 cm individuals for the woodland (Figures 5). Young individuals (0 - 10cm) and adult individuals (20 - 30 and ≥ 30 cm) are poorly represented. On the other hand, for the tree savannah (SA) and shrub savannah (SU) these distributions have the shape of an inverted "J" or "L", characteristic of a vegetation types dominated by a large number of young subjects, a small number of individuals with a large diameter, with a regular reduction in the number of individuals when the diameter increases.

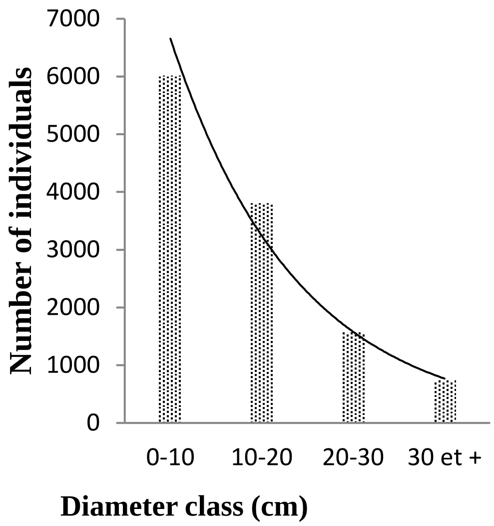

Figure 4: Diameter class distribution of MNP vegetation as a whole

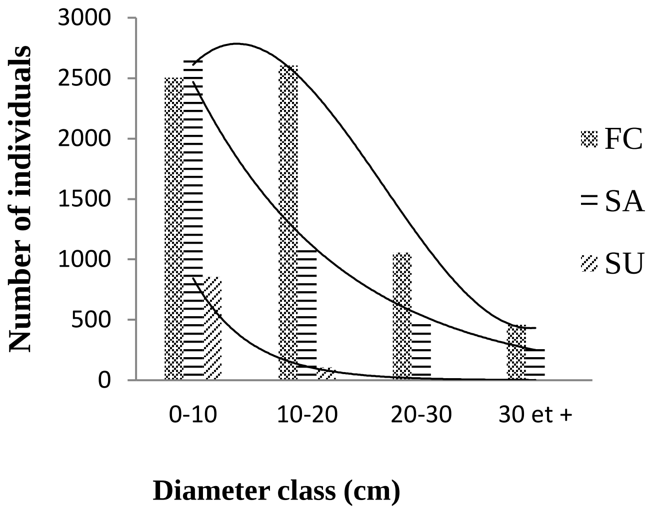

Figure 5 Diameter class distribution of the 3 vegetation formations of the MNP: woodland (FC), Tree savanna (SA) and Shrub savanna (SU).

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3-7 Height Class Distribution

Like diameter, the height class distribution of woody species in the park's overall vegetation is "L" shaped (Figure 6). The vegetation cover of the MNP is dominated by young individuals ranging in height from 3 to 6 m. These are more numerous than the mature individuals.

The height class distributions for the three vegetation types in the MNP are different (Figure 7). In the woodland, the trend line of the height class distribution is bell-shaped. In contrast, in the tree and shrub savannahs, the height class distributions are "L" shaped, indicating a downward trend in the number of individuals from lower to higher classes. The shrub savanna contains a low proportion of individuals in height classes above 9 m.

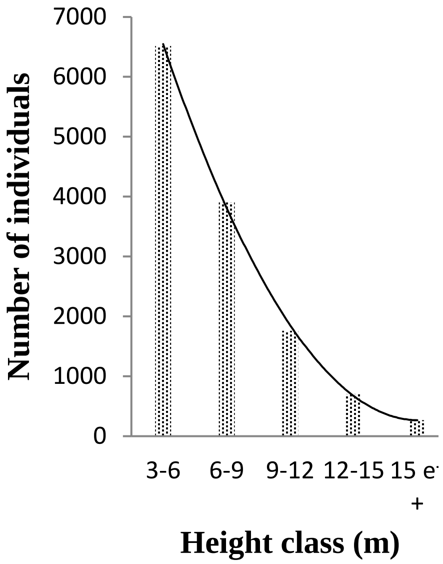

Figure 6: Height class distribution of woody vegetation in the MNP as a whole.

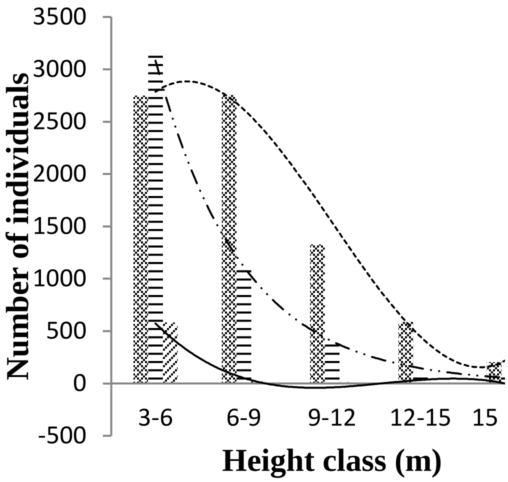

Figure 7: Distribution of height classes of woody plants in the three vegetation types of the MNP: woodland (FC), tree savanna (SA) and shrub savanna (SU).

3-8 Linear regressions between diameter and height

The relationships between diameter at 1.30 m and total height are shown in Figure 8. These relationships are linear, positive and significant ($P<0.001$), for the whole vegetation of the MNP in general, as well as for the three (03) vegetation formations (FC, SA and SU) in particular. The coefficients of determination (R^2) vary from 0.328 for the woodland to 0.597 for tree savannah.

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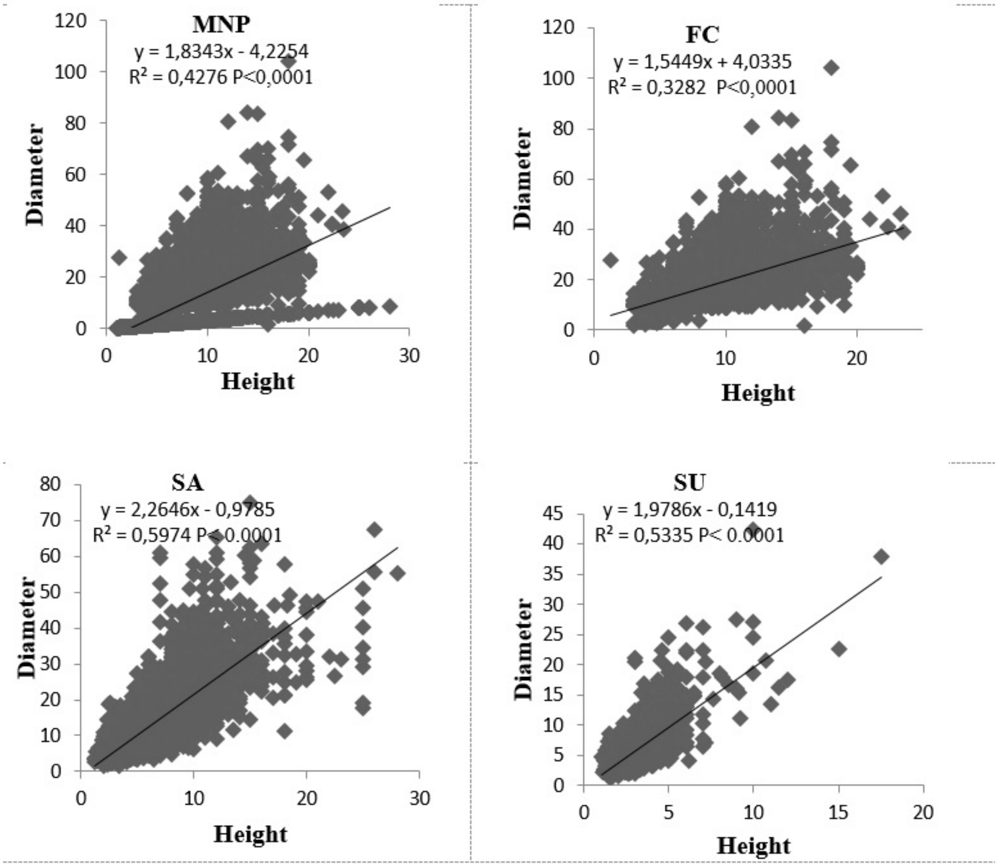

Figure 8: Linear regressions between height and diameter of the vegetation of the MNP in general and its three (03) vegetation formations: woodland (FC), Tree savannah (SA) and Shrubby savannah (SU).

4-Discussion

4-1 Specific composition of the PNM

The results on the specific composition show that the vegetation of MNP is very rich (102 species, 81 genera and 34 families). We also note a dominance of species such as *Anogeissus leiocarpa* (28.24%) in the woodland, *Detarium microcarpum* (21.28%) and (22.30%) respectively in the tree savanna and shrub savanna, *spermacoce chaetocephala* (13.56%) in the grassy savanna. The families most represented and common to the four vegetation types studied are Fabaceae, Malvaceae and Rubiaceae. This result is similar to that found by Kimpouni *et al.* (2019) (106 species, 83 genera, and 36 families) but far from that of Saradoum (2012), who recorded 520 species, 295 genera, and 82 families in the same study area. This great difference in species, genera and families in 8 years between this article result (2020) and that of Saradoum (2012), is explained by the fact that this article does not have the same objective and this study did not take place in the same sites as Saradoum.

However, according to Marcon (2011), increasing the sampling area is not always a suitable solution in the tropics, since it always results in an increase in the number of species. It is important to know that the larger the area, the greater the chance of having a very high floristic diversity, especially in this case study. This may also indicate that there is a strong pressure on the vegetation of the MNP. The low richness of species, genera and families in the savannahs (shrub and grassy) would be linked to the strong pressure exerted by the local residents and livestock on the vegetation of these savannahs. Madjimbé *et al* (2019) revealed in their research in the same area that the most important families are Fabaceae and Combretaceae. Regarding the highest number of genera per family and the most abundant species, these results corroborate the results of Saradoum (2012), Ndotam *et al.* (2017) and Kouyate *et al*. (2020). The latter, in their study found that species of the family Combretaceae, Poaceae, Fabaceae, Rubiacea and Apocynaceae were the most numerous and the most abundant species are *Prosopis africana*, *Detarium microcarpum, Flueggea virosa, Piliostigma reticulatum* and *Anogeissus leiocarpa*.

4-2 Density and Stand Basal Areas

The highest densities and lowest basal area are observed in the shrub savanna, because the vegetation is dominated by species consisting not only of small diameter individuals, but also in small numbers such as *Grewia flavescens, Grewia venusta* and *Bridelia ferruginea*. The variation in density and basal area between vegetation types is due to the size of the trees in the vegetation types. The larger the trees in a vegetation types, the less dense they are. Human pressure in woodland and tree savanna could be explained by the low presence of reproductive individuals due to abusive exploitation, especially of woody forest products (Kouyate *et al*., 2020). These results are confirmed by Diouf *et al*. (2019) who indicate that the low basal area is explained by the presence of a strong community of small diameter reflecting a stand with shrub dominance. Regarding the species with high basal area, these results of this article are similar to that of Wanie (2020) who found basal area dominance is due to individuals with developed trunks such as *Anogeissus leiocarpa, Acacia polyacantha, Faidherbia albida, Tamarindus indica*, and *Balanites aegyptiaca* and those of Baggnian *et al*. (2019), the lowest basal area because the flora is dominated by species such as *Guiera senegalensis* and *Hyphaene thebaica* that are shrubs, with small trunks.

4-3 Diversity index

The calculated Shannon diversity indices indicate high species diversity in woodland and tree savanna (H'>2.5bits), but moderate floristic richness in shrub savanna (H'< 2.5 but >2). The low values of the equitability

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index in all vegetation units (between 0.19 and 0.25) indicate a poor equi-representation of individuals between the different species and for the three (03) vegetation types. As for Simpson's index, its values are close to 1 in the different vegetation formations, reflecting the high probability that two randomly selected individuals are of different species. The average floristic diversity observed in the shrubby savannah would be linked to anthropic activities. The low values of equitability of Piélou, according to Fongnzossie *et al*. (2019) is a massif in transitional phase and under the influence of disturbance stress. The comparison of the woody flora counted, in the different vegetation types on the basis of the Jaccard index associated with the Hamming distance shows a small floristic difference between FC and SA, with the value of Jaccard index of 70.23% and the corresponding Hamming distance is 29.76%. On the other hand, between FC and SU and between SA and SU, the floristic difference is medium with respective Jaccard index values of 56.06% and 45%, and the corresponding Hamming distances of 43.93% and 55% respectively. There is thus a heterogeneity of the massif in relation to the shrub savanna. The latter is distinguished from the other vegetation types by its state of degradation. The differences between the vegetation types would be due to the influence of anthropogenic activities such as bushfire and livestock (Figures 9 and 10). Nyasiri (2018) believes that in addition to anthropogenic activities, climatic and edaphic factors influence species development.

Figure 9: Negative impact of bush fires on MNP vegetation

Figure 10: oxen grazing in the MNP

4-4 vegetation types characteristics

The distribution of diameter classes showed variation across vegetation types. In the woodland the horizontal structure is asymmetrically bell-shaped to the right, centered on individuals 10-20 cm (Figure 5). Young individuals (0- 10cm) and adult individuals (20-30cm and 30+) are poorly represented. This type of distribution is characteristic of mono-specific stands with very low regeneration potential (Kouyate *et al*., 2020). The "inverted J" or "L" shape (Figure 5) was observed in the Tree Savanna and Shrub Savanna, characteristic of a type 1 stand, dominated by a large number of young individuals, a small number of large individuals with a regular reduction in the number of individuals from one size class to the next. This type of structure is characteristic of a stable stand with a strong presence of individuals in the young classes (Diouf *et al*., 2019). This indicates that large individuals are highly exploited as noted by Idrissa *et al*. (2020). This type of form is characteristic of multi-species stands with a predominance of young individuals ensuring a high regeneration potential (Sandjong, 2018). The predominance of young individuals can be explained by the relationship between species temperament and height distribution (Kouyate *et al*., 2020). However, the survival of these young individuals is problematic due to bush fires and overgrazing. In contrast, species that are resistant to bushfire have a high proportion of mature individuals (Nkongmeneck *et al*., 2010; Kouyate *et al*., 2020).

5. Conclusion

The floristic inventory of the Manda National Park has allowed us to record a total of 12885 individuals belonging to 103 species, 81 genera and 34 families. The most represented families are Fabaceae (24 species), Combretaceae (10 species), Poaceae (9 species), Rubiaceae and Malvaceae, each with 8 species. The highest average density per hectare is found in the shrubby Savanna (3507ind/ha). The highest basal area is observed in the woodland and the highest rate of natural regeneration of species in the shrub savannas. However, analysis of the diameter structure in the tree and shrub savannas showed the existence of a high regeneration potential in contrast to the woodland. There is a floristic richness in the woodland and the tree savannah, but the low values of the equitability index (less than 0.5) indicate a poor distribution of individuals between the different species and for the three (03) vegetation types. These results allow us to conclude that the Manda Park has a good specific diversity and is under anthropic pressure through the destruction of its vegetation cover. In order to promote good management of the park, it is essential to conduct such analyses on biological traits, in a staggered manner in time and space. Strategies must be developed to ensure conservation, survival of natural regeneration, and allow for low-cost propagation activities of local forest species.

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