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Typology and structural characteristics of the woody population of oasian basins in south-eastern Niger

Douma Soumana[1], Salamatou Abdourahamane Illiassou[2*], Boubacar Moussa Mamoudou[2], Daouda Gazali[1], Adamou Didier Tidjani[3], Ali Mahamane[1,2]

[1]Université Abdou Moumouni de Niamey, Département de Biologie, Faculté des Sciences et Techniques, BP:10662 Niamey, Niger
[2]Université de Diffa, Faculté des Sciences Agronomiques, BP 78, Diffa, Niger
[3]Université Abdou Moumouni, Faculté d'Agronomie, B.P. 10960 Niamey, Niger.
*Corresponding Author

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***Abstract*— The present study aims to characterize the typology of woody stands in oasis basins in the Gouré department: the case of Balla, Kilakina and Tchago. In these oasian basins, 75 survey plots of 50x50m² were carried out in order to collect informations about le floral of the area and its dendrometric characteristics. The woody stand of the basins contains a total of 26 woody species divided into 23 genera and 16 different families. The most represented families are: Mimosaceae (7 species or 26%), Arecaceae (2 species or 7.79%), Asclepiadaceae (2 species or 7.79%), Anacardiaceae (2 species or 7.79%) and Myrtaceae (2 species or 7.79%).The characterization of the woody stand of the oasis basins of Gouré according to the importance value index showed that Hyphaene thebaica (L.) Mart has the highest contribution (852.7 points), and Adansonia digitata L., the least (59.28 points). Three plant groups were identified based on the ascending hierarchical classification from 15% similarity and the dendrometric structure of each group was established. The later defined a positive asymmetric distribution characterizing the dominance of young individuals. Based on the above results, the diversity of the oasian basins is high. Nevertheless, this biodiversity is exposed to severe climatic conditions and anthropogenic pressure, which makes its vulnerability. In this circumstance, our study remains as a tool for better management and exploitation of this woody stand.*
Keywords*— Oasian basins, flora, vegetation structure, eastern Niger.

I. INTRODUCTION

In west Africa, the Sahelian domain corresponds to the transition zone between the desert region and the Sudanese region. The first, characterized by hot weather and the later by sufficient rainfall and less vulnerable crops to climatic hazards. Sahel region is an agropastoral zone by excellence which suffer severe degradation for several decades due to worsening climatic conditions and increasing anthropization (Albergel et *al.*, 1986). The conjunction of these natural and anthropogenic phenomena results in deforestation, soil degradation and desertification (Toko and Sinsin, 2008). Its local communities are hence confronted with a multitude of interactive factors (climate, demography, epidemics, epizootics, locust invasions, unsuitable socio-political, economic and cultural systems, etc.) which considerably limit their adaptive strategies to the environment.

Niger, a Sahelian country, is not an exception. It has indeed been affected by recurrent droughts since the end of the 1960s; the most terrible of which were those of 1972/73 and 1983/84. Nevertheless, these disturbances are becoming more frequent and intense and generate significant impacts. The most visible are the decrease in agricultural and animal production, the degradation of natural resources (water, soil and vegetation) and erosion, thus making food security, environmental management and livelihood precarious. This situation exacerbates the vulnerability of these nigeriens populations.

Several localities are affected by this situation and the department of Gouré, located in the Zinder region, in the east of the Republic of Niger is among the most affected areas by these recurrent droughts , since the end of the 1960s (Ozer et *al.*, 2005). It is patterned with closed depressions commonly referred to as the oasian basins (karimou, 2017). These basins are characterized by three to four inter-dune depressions of varied cross-sections where the vegetation and soil types are organised in concentric aureoles descending gently towards the center with invariably the external aureole consisting of sand dunes, the second aureole of dense palm trees, the third aureole made up of market gardening and finally the central one characterised by more or less natronised bare soil, however, depending on the morphology of the basins, it could be occupied by a pond (PLECO, 2006).

In this area, the active sand dunes are present for nearly 200 km between Gouré and Maine-Soroa, constantly threatening the infrastructures, (such as roads and housing) and these oasian basins which suffer already from general degradation due to wind erosion, silting up, the drop in groundwater levels and the strong pressure on woody resources (Ozer et al., 2005; karimou, 2017).

All these threats to which insufficient rainfall could be added ,repeatedly causes a deficit in agricultural production and the migration of certain species (PLECO, 2010). Despite the role of these basins in the socio-economic life of local populations, these ecosystems do not benefit from any conservation measures and little is known in the scientific literature in Niger. In line with the sustainable exploitation of these resources, it is imperative to carry out more investigations in order to have scientific data, essential tools for the development of sustainable management plans. Hence, the framework for this study, which focuses on the typology and structural characteristics of the woody population of oasian basins.

II. METHODS

Description of study sites

The study was conducted Southeast of the 14th parallel between 09°45'and 11°15' East longitude and the department of Gouré (region of Zinder) which covers an area of 20,517 km² in the Manga oasis system. The area is bounded to the east by the department of Goudoumaria (Diffa region), to the north by the department of Tesker, to the south by the department of Magaria and the Federal Republic of Nigeria and to the west by the department of Mirriah and Tanout (Figure 1).

The department of Gouré is between the isohyets 150 and 400 mm. Its climate is Sahelian type, and is characterized by two distinct seasons: dry and raining seasons.

Three basins were selected in this department namely Balla, Kilakina and Tchago (Figure 1& 2). They are:

- **Balla site**

The Balla basin, falls under the canton of Gouré and extends over a strip of about 10 km. Located 25 km from Gouré in the center area and 2 km from the edge of the RN1 (13°53'50.89"N latitude and 10°24'31.6 " East longitude). This site has three or even four sectors namely the doum belt, the zone exploited under market gardening, the salt zone exploited under market gardening and the strongly salty zone very weakly represented. The village bears the same name as the basin and also has a second basin which is mainly for pastoral purposes and reserved for watering animals, whiles the first is reserved for crops. The village is mainly made up of the Kanouri who have for main activity the exploitation of the basin. However, this basin is also exploited by neighboring villages namely: Ballabré and Allajiri (Issaka, 2018).

- **Kilakina site**

The kilakina site located in the urban commune of Gouré is located 62 km east of the city of Gouré on RN1 (13°43'72.8" North latitude and 10°44'80.5" East longitude). The basin, with intermediate water, is for agro-pastoral purposes. It has a total area of 56 ha, of which 35 are exploitable and 25 are exploited, i.e. 71.4%. It is a large basin which is exploited throughout the year. This site has four very distinct sectors. These are the doum belt, the zone exploited under market gardening and arboriculture, the zone exploited under market gardening and arboriculture which is salty and the naturally natroned bed. According to the population, the village has around more than 1,500 inhabitants and 54 farms (Issaka, 2018).

- **Tchago site**

The Tchago site is located 23 km north-west of the department of Gouré (14°02'30" and 14°02'52" North latitudes and 10°03'39" and 10°04'06" longitudes East). Tchago is one of the villages with a large number of basins in the department of Gouré. There are five (5) basins, the first of which has an area of 1.94 ha, is located southwest of the village at a distance of fifty 50m, the second, the largest of 5 hectares and the most exploited, is also located to the southwest of the village at a distance of 1 km, the third of 0.4 hectares, located to the south of the said village at a distance of 2 km, the fourth of 0.5 hectares, contiguous to the villages of Tchago and N 'Gouro Guidimi, the fifth of 1 hectare is also contiguous to the villages of Dagradi and N'GousroGuidimi and finally a great depression to the West and North of about 20 hectares in which rainfed crops are cultivated. The cultivated plots are fenced by a dead hedge of *Prosopis juliflora* associated with branches of *Phoenix dactylifera*. The cultivated areas in these basins represent only about 1/4 of the total area. (Issaka, 2018). Tchago has two sectors: the doum belt and the zone exploited under arboriculture and market gardening.

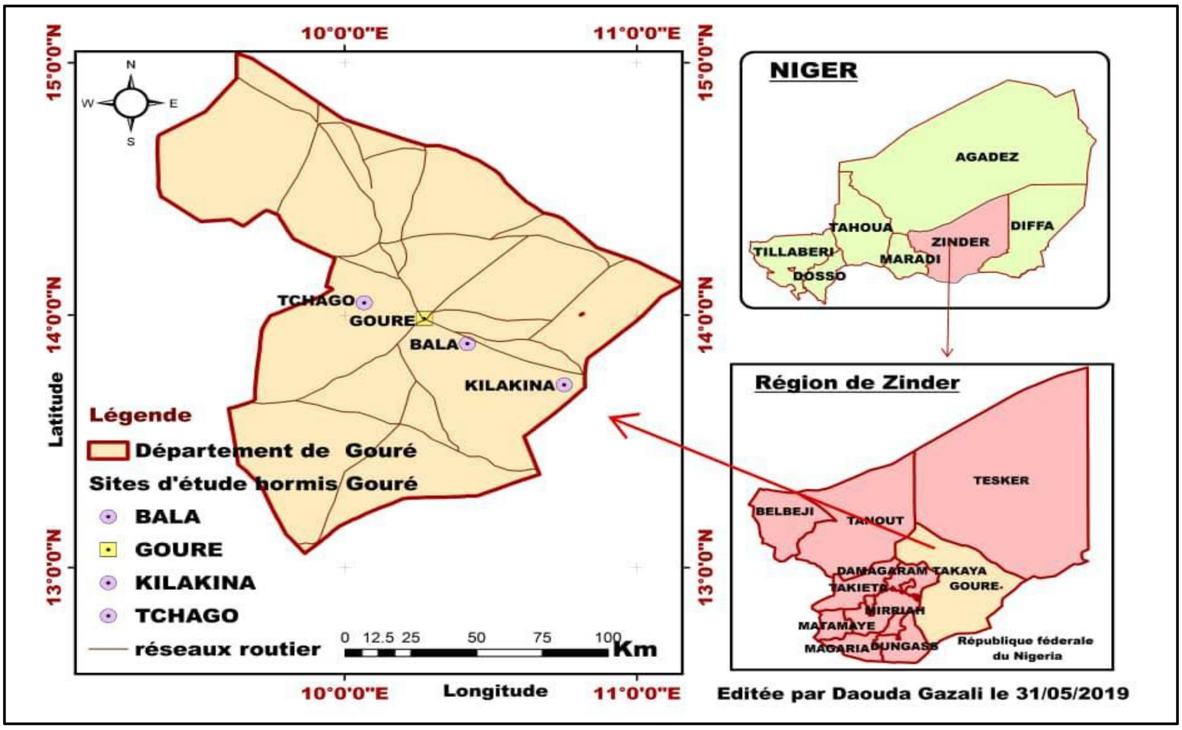

Fig.1: Study sites locations

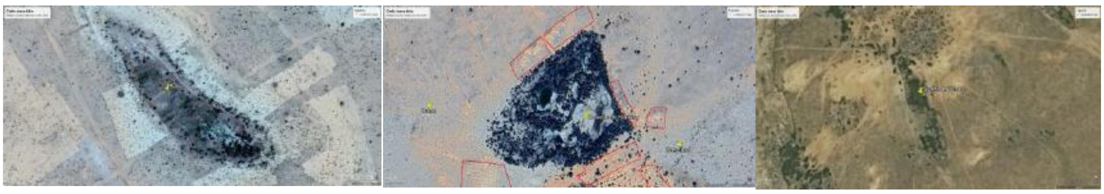

Fig.2: Satellite view of the three sites

Data Collection

In each of the three basins, data was collected using the radiar transect method as defined by Douma (2016). Thus, eight transects were installed from the center of the bassin with a spacing of 45° between the transects. On each of them, four vegetation inventory plots of 2500 m^2 (50mx50m) have been placed at an equidistance of 500 m between plots. In total, 75 vegetation plots were carried out.

In each plot, parameters such as woody density, total height, diameter at 30 cm from the ground and the two crown diameters were measured. The floristic list was established on the basis of the Flore du Sénégal by BERHAUT (1967).

Table 1: Number of transects and surveys carried out in the study area

Village	Balla	Tchago	Kalakina	Total
Ethnic group	Kanouri	Kanouri	Kanouri	
Number of transect	8	8	8	**24**
Number of sampling	26	23	26	**75**

Data processing and analysis

❖ Several indices were estimated. The diversity of the ligneous plants was evaluated by the calculation of :

(1) **The Shannon diversity index, Weaver (1949) (*H*)**formulated as follows (1) :

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

n = total number of species; ni = number of individual of species i.

This index, expressed in bits, is based on information theory. It varies between 0 (zero diversity) and more than 5 bits (very high diversity) (Frontier and Pichod-Viale, 1993).

(2) **The Pielou equitability index (1966) calculated as follows:**

$$E = \frac{H'}{Log2\ S};$$

H'= observed diversity ; $\log_2 S$ = maximum theoric diversity, E= equitability et S = specific richness.

It varies between 0 and 1. It tends towards 0 when there is a phenomenon of dominance and towards 1 when the distribution of individuals between species is regular (no phenomenon of dominance).

(3) The Species Importance Value Index (IVI), developed by Cottam, Curtis (1956), characterizes the place occupied by each species in relation to all species of vegetation. It was calculated to assess the specific preponderance according to the formula (Kouamé, 1998):

IVI = *FREQesp* + *DENSesp* + *DOMesp*,with :

FREQesp, the relative frequency of a species: it is the ratio of its specific frequency (number of plots in which it is present) to the total of the specific frequencies; *DENSesp*, the relative density of a species; it is the ratio of its absolute density to the total of absole densities; and *DOMesp*, the relative dominance of a species; it is the quotient of its basal area (basal area) by the total of the basal areas of the species. and. Specific diversity is defined both in relation to the number of species present (specific richness).

❖ The structural parameters used to characterize the stands are:

(1) the density which expresses the total number of trees per unit area (hectare)

(2) basal area, (en m^2/ha)) was calculated according to the relation:

$$G = \frac{\pi d^2}{4}$$

With G in (en m^2/ha) and d expressing the diameter at 1.30 m.

From a threshold of 5 cm, diameter classes of 5 cm amplitude were formed. These classes helped to establish distribution histograms of the diameter.

A test of fit to the theoretical Weibull distribution (Rondeux, 1999) was carried out using the Minitab 16 software. The theoretical Weibull distribution with three parameters (position a, scale or size b and shape c) was used to characterize stand structure, thanks to its flexibility of use and great variability; of the forms of distribution it produces. The parameter a corresponds to the threshold value, that is to say to the smallest value of diameter (respectively height) retained for the constitution of the histograms. The parameter b is linked to the central value of the distribution of the diameter and height classes. Finally, the parameter c is linked to the observed structure and, depending on its value, leads the Weibull distribution to take several forms.

The overlap gives the average of the dominant abundance class of each species in the stand. It plays an important role in the study of vegetation. It is calculated from the following formula: $Rm=\sum Ri/n$ with Ri the recovery of i^eme^ reading and n the number of reading.

In order to characterized a plant group in the oasis basins, an ascending hierarchical classification of the 75 surveys using the PC-ORD software was done with a dissimilarity rate of 30%.

III. RESULTS

➢ **Floristic richness of the oasian basins**

The woody stand of the basins contains a total of 26 woody species divided into 23 genera and 16 different families. The most represented families are: Mimosaceae (7 species or 26%), Arecaceae (2 species or 7.79%), Asclepiadaceae (2 species or 7.79%), Anacardiaceae (2 species or 7.79%) and Myrtaceae (2 species or 7.79%). These families represent 58.08% in total. The remaining families are poorly represented. These are the Balanitaceae, Bombacaceae, Burseraceae, Caesalpiniaceae, Capparaceae, Lythraceae Euphorbiaceae (Figure 2).

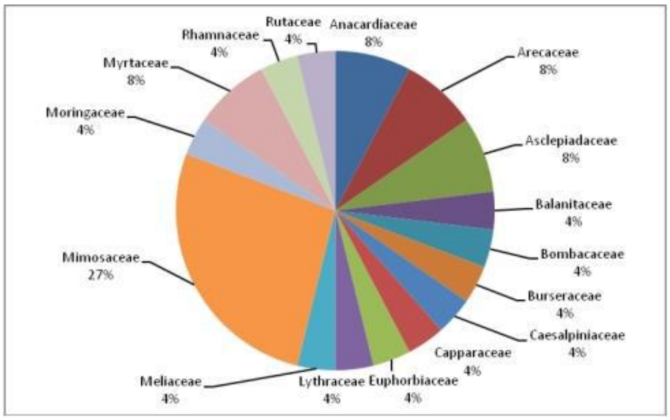

Fig.2: Specific family composition of the oasian basins

➢ **Characterization of the woody stand of the basins**

The characterization of the woody stand of the oasis basins of Gouré according to the importance value index shows that *Hyphaene thebaica* (L.) Mart has the highest contribution (852.7 points), followed by *Leptadenia pyrotechnica* (614.85 points), *Prosopis juliflora* (473.2), *Phoenix dactylifera* L. (415.77 points), *Lawsonia inermis* L. (321.96) and *Calotropis procera* (223.28 points) (Table 1). *Hyphaene Thebaica is therefore the species of greatest ecological importance.* and can be used, on its own, to designate the stand.

Table 1: Woody species predominance in the basins

SPECIES	Total Number	Relative Frequency	density (Ind/ha)	St (m^2)	Plant cover (m^2)	IVI
Hyphaene thebaica (L.) Mart.	737	22,9	35,09	33,86	23,88	852,73
Leptadenia pyrotechnica (Forssk.) Decne	570	17,71	27,14	0	0	614,85
Prosopis juliflora (Sw.) D.C.	415	12,89	19,76	6,4	19,15	473,2
Phoenix dactylifera L.	318	9,88	15,14	42,86	29,89	415,77
Lawsonia inermis L.	298	9,26	14,19	0,02	0,49	321,96
Calotropis procera (Ait.) Ait. F.	207	6,43	9,85	0	0	223,28

Azadirachta indicaA.Juss.	141	4,38	6,71	6,62	27,91	186,62
Acacia raddiana Savi	133	4,13	6,33	1,08	8,49	153,03
Euphorbia balsamifera Aiton	70	2,17	3,33	0	0	75,5
Acacia senegal (L.) Willd.	63	1,95	3	0,31	7,56	75,82
Citrus limon (L.) Burm.f.	37	1,14	1,76	2,44	37,63	79,97
Faidherbia albida Del.	36	1,11	1,71	7,18	35,62	81,62
Adansonia digitata L.	35	1,08	1,67	9,08	12,45	59,28
Others	31	0,93	1,44	3,68	128,73	165,78

- **Vegetation groupings**

Three plant groups were identified based on the ascending hierarchical classification from the 75 vegetation plot matrix and 26 species at a rate of 15% similarity (Figure 3). Group I (G1) is represented by 26 records and 21 species The majority of these surveys were carried out at the village of Balla (46.15%), and Kilakina and Tchago recorded respectively 36.46% and 15.38%. The species presenting this group are: *Hyphaene thebaica* (31.46%) followed by *Prosopis juliflora* (19.69%); *Phoenix dactylifera* (15.15%), *Euphorbia balsamifera* (6, 75%); *Lawsonia inermis* (6.27%) and *Azadirachta indica* (4.15%). These species are found mostly on soil characterised by 69.23% clay texture. It also represents a transition zone between the lower slope and the valley floor, therefore a relatively medium slope. At this level, the average species density is 159.38 ± 12.7 plants / ha with an average cover of 31.40%. The basal area of the trees is low 0.90 ± 0.86m² / ha.

Group II(G2)has 33 records for a total of 24 species. 48.48% of the surveys were carried out in the village of Tchago, 30.30% in Balla and 21.21% in Kilakina. The woody flora of this group is characterized by species such as *Leptedania phyrotechnica* (23.61%); *Lawsonia inermis* (17.17%) *Hyphaene thebaica* (13.01%); *Prosopis juliflora* (12.15%); *Phoenix dactylifera* (9.19%) and *Azadirachta indica* (6.85%). These species are found on the sandy-clay texture mid-slope. The tree density in this environment is 155.15 ± 9.93 individual per hectare with an average cover of 36.46%. But these trees give this environment a basal area of 25.67m².

Group III (G3) includes 16 surveys and presents 19 species. These surveys were carried out in the village of Balla (56.25%), Kilakina (43.75%) and Tchago (6.25%). The dominant species in this group are *Hyphaene thebaica* (33.7%), *Leptedania phyrotechnica* (17.12%); *Calotropis procera* (14.77%); *Acacia raddiana* (10; 36%) *Prosopis juliflora* (7.89%); and *Phoenix dactylifera* (5.52%) At this level the slope is relatively low.

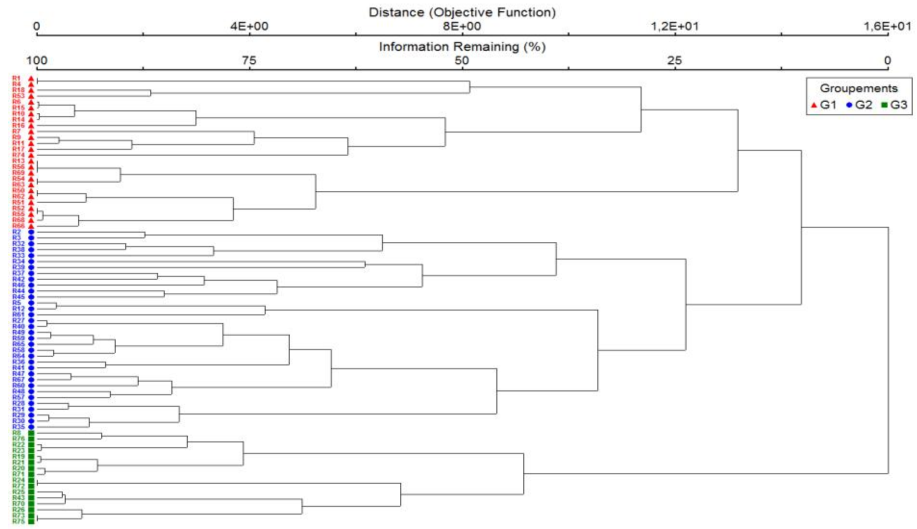

Fig.3: Ascending Hierarchical Classification (CHA) of readings based on a factorial correspondence analysis.

➢ **Diversity and equity of groups**

Table 2 shows the variation of species richness, Shannon diversity index and Pielou equity indices for each group. It appears that group 3 is relatively less diversified in taxa compared to the other two. This is confirmed by the values of the Shannon diversity index (H '= 2.89 and E = 0.68 bits) against respectively (H' = 3.04; E = 0.69) and (H '= 3.32 and E = 0.72) for groups 1 and 2.

Table 2: Species diversity of the different plant groups in oasian basins

Group	S	H'	E
Group 1	21	3,04	0,69
Group 2	24	3,32	0,72
Group 3	19	2,89	0,68

➢ **Dendrometric characteristics of the groups**

Structural characteristics of stands

Table 3 shows the structural dendrometric parameters determined within these three groups. Group I and III have the highest density (159.38 ± 12.17 and 181 ± 15.62 plants / ha) respectively, while the third has the lowest density (155.15 ± 9.93 plants / ha).

Table 3. Structural parameters determined within these three groups

Groups	Density (individuals/ha)	Basal area(m^2/ha)	Plant cover (%)
Group 1	159,38 ± 12,71	0,90 ± 0,86	31,40%
Group 2	155,15 ± 9,93	1,33 ± 1,92	36,46%
Group 3	181 ± 15,62	0,98± 1,28	32,15%

Population structure of the settlement

Distribution by size

Figure 4 below represent the distribution of individuals of the three identified groups.In general, the structure is bell-shaped for all individuals and for the three groups.

The histograms of group I are of a stable type characterized by a large number of individuals of small size classes (young subjects), a small number of large individuals (adult subjects) in the intermediate classes and a regular reduction in the number of individuals. aged upper classes. This type of distribution fits with a theoretical Weibull distribution with a shape parameter c = 1.37 (1 <c<3.6) characteristic of a predominance of young individuals or small diameters.

The diametric structure of the individuals of group II is also characterized by a predominance of individuals of small diameter. This distribution histogram of the observed diameter classes shows a straight asymmetry appearance (1 <c <3.6), characteristic of populations with a relative predominance of young individuals or of small diameters. Meanwhile, the structure of individuals in group III stood out from the others by a high density of individuals in the large intermediate classes (30-40). The analysis of the diameter structure of the present woody plants fits the theoretical Weibull distribution with the shape parameter c = 1.039 (1 <C <3.6).

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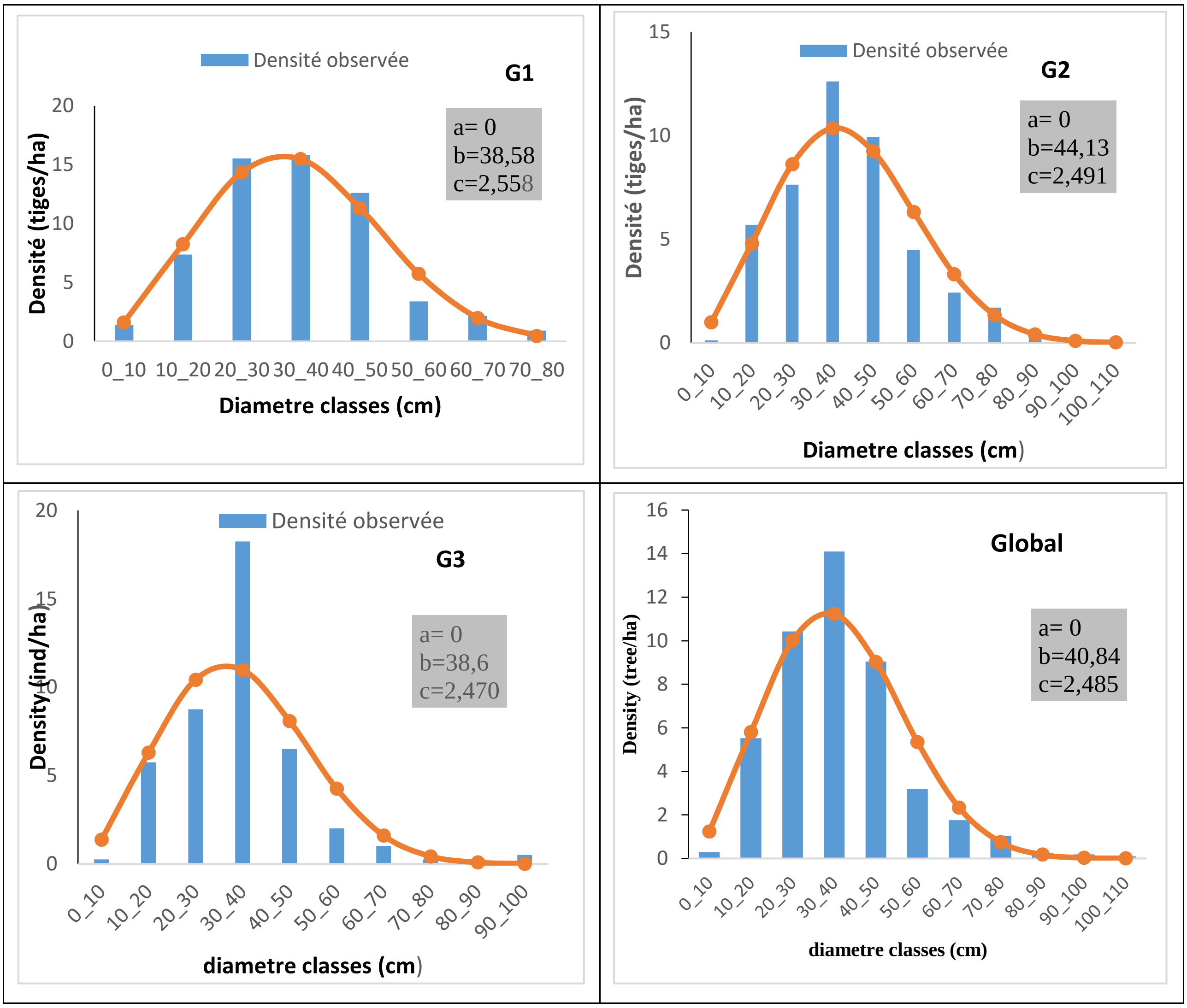

Fig.4: Diameter structure for all woody individuals and for the three plant groups.

IV. DISCUSSION

The woody flora of the Oasian basins of Gouré contains 26 woody species divided into 23 genera and 16 families. This richness is much greater than that obtained by Kaou et al. (2017), on the dunes of Mainé Soroa where they identified 10 woody species divided into 5 families and 8 genera with a dominance of Mimosaceae (37.5%) and Asclepiadaceae (25%). This difference can be linked to the level of organization of the soils in a halo or aureole and to the level of the water table. The basins in the Gouré area seem to be better organized than those in the Mainé area. Indeed, when the soil is well organized, a relatively flat unit is formed, colonized by woody plants dominated by palm date trees and acacias (*A. seyal* and *A. nilotica*) with sporadic doum trees (PAGRN, 2005). This vegetation belt reduces wind speed and in turn weakens erosion, and improves the microclimate for good vegetation establishment (van Aarde et al. 1996).

The best represented families are the Mimosaceae, the presence of which indicates a dry climate (Mbayngone et al., 2008). The most frequent species in these basins are *Hyphaene thebaica, Prosopis juliflora, Leptadenia pyrotechnica and Phoenix dactylifera*. These species are characteristic of this particular ecosystem type. Their importance depends on environmental conditions, in particular the intensity of anthropogenic pressure. These species are arranged in a halo from the outside to the inside of the basin with a high concentration of *Hyphaene thebaica* in the outer belt (PLECO, 2006) and date palms on its inner periphery. This density varies according to the sites, which is itself explained by a variation in the level of the depth of the water table. This has already been observed by (Issa et al. 2016; and Souley, 2017). However, in terms of floristic richness, the Sorensen index showed great similarity both between the sites and between the concentric halos, which could mean that the three sites share the same environmental conditions. Regarding the diversity of the woody stand, we observe a high diversity in these basins despite disturbances due to human activities of the population including trampling. This means that the operation does not affect the diversity of the pits. According to Forman and Godron (1986) and Burel and Baudry (1999), up to a certain threshold, disturbances increase the diversity of an ecosystem. These authors indicate that the disturbances are intense of the peripherals generally tend towards a diversification while in the internal zones with weak disturbance tend towards a tend towards a homogenization of the medium (Barot et al., 1999; Henkel, 2003). They explained this state of affairs by a change in facies induced by the edge effect which promotes both the heterogeneous development of certain species such as heliophilic species, ruderal species and that of species adapted to various disturbances (trampling, water stress and human activities) (Tomimatsu and Ohara, 2004; Verheyen and Hermy, 2004; Harper et al., 2005).

Considering the villages, there is a variation in diversity which may be due to the variation in the level of the shallower water table and to the way in which the woody stand is managed by the local populations. This shows that the Balla site is the least diversified of the three sites. This low diversity seems to be due to the resurgence of bush fires which have had an impact on certain species (Tidjani,2016). Overall, it is at the level of the second halo that the lowest density is recorded. On the other hand, the recovery rate is very high. This means that the stand is made up of large trees with a giant habit. The soil appears to be fertile and *Hyphaen tebaica* is the dominant species, these 80% surrounded pits are surrounded by Arecaceae with a specific contribution between 60-92.6%. Analysis of the structure of the woody stand shows a distribution characterized by the predominance of young individuals or of small diameters. Individuals between the 30 to 40cm class are best represented. This type of distribution was described by (Volle, 1985) in an environment with little or no grazing where the relatively low population densities corresponded to a recent installation or to aging. Environmental factors play a significant role in the discrimination of plant groups (Ababou et al., 2009).

The three individualized plant groups explain the heterogeneity of the stand. These groupings, although distinct, are 80% similar. The valuesof the diversity indices show that the species therefore share the ecological niche in an equitable manner. Group I which brings together the 21 species distributed in 26 predominantly *Hyphaene thebaica*. It is made up of readings from the natron zone and those from the market gardening zone which corresponds respectively to the third and fourth halo of the basins. This group represents the transition zone between the lower slope and the valley floor. This transition zone is also characterized by a relatively medium slope and a 69.23% clay texture. Factors, soil types and the intensity of anthropogenic pressure seem to explain the aggregation of species in this grouping. The average density of the species is 159.38 ± 12.7 vines / ha with an average crown cover of 31.40% and a basal cover of 0.90 ± 0.86m² / ha.

Group II corresponds to the vegetation of the transition zone between the second and third halo of the basins, ie between the zone of market garden crops and the strip of palm groves. The woody flora of this group is predominantly Leptedania phyrotechnica..C is the sandy-clay texture mid-slope which most often represents a meadow established under the edge effect. The tree density is 155.15 ± 9.93 vines / ha which provides an aerial cover of 36.46%. Trees seem to be better adapted to this environment. The basal area of 25.67m².

Group III, which includes months of surveys and less species. These surveys were carried out in the village of Balla (56.25%), Kilakina (43.75%) and Tchago (6.25%). It corresponds to the vegetation that overlaps between the second and first sandy texture halo. This is the transition zone between the palm grove and the dune front. The dominant species in this group are *hyphaene thebaica* (33.7%), *Leptedania phyrotechnica* (17.12%); *Calotropis procera* (14.77%); *Acacia raddiana* (10; 36%) *Prosopis juliflora* (7.89%); and *Phoenix dactylifera* (5.52%) At this level the slope is relatively low.

Analysis of the woody stand structure of these oasis basins shows an asymmetric distribution of individuals characteristic of monospecific stands and a dominance of individuals with small diameters. This result is consistent with that of Aboubacar, et al., 2016) in the Dallol Bosso. For the height structure, in the study area and for the different groupings, the distribution also has the same shape as that of the diameter which is a positive asymmetric distribution with a predominance of young individuals, which is said to be disturbances (natural and anthropogenic) recurrent.

V. CONCLUSION

The present study contributes to the existing information on the woody population of the oasisian basins of Gouré. The flora of this stand is rich in 26 species divided into 23 genera and 16 families. The dominant family is Arecaceae (33%) followed by Asclepiadaceae with 24% Mimosaceae 21%, Lytraceae 9% and finally Meliaceae 4%. The average tree density is estimated at 132.87 vines / ha. It is a relatively covered, diverse stand. Analysis of the demographic structures of the trees in these present basins shows a positive asymmetric distribution characterizing a monospecific population. Floristic compositions vary from one site to another; the hierarchical classification has made it possible to distinguish three groups of vegetation: (1) Group I, which groups together the species in the transition zone between the lower slope and the valley floor. The soil type factors and the intensity of anthropogenic pressure seem to explain the grouping of species. (2) Group II corresponds to the vegetation of the transition zone between the second and third halo of the basins. It is the mid-slope with a sandy-clay texture that most often represents a meadow installed under the edge effect. (3) Group III which includes fewer surveys and species.

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