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Diversity and structure of woody stands in the contracted vegetation of western Niger following a rainfall and anthropisation gradient

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***Abstract*— The aim of this study was to characterise the diversity and structural parameters of the woody stand in the contracted vegetation of western Niger at three sites located along a rainfall and human settlement gradient. An inventory of the woody flora and a measurement of the dendrometric characteristics of the trees were carried out on 120 plots of 2500 m2 subdivided into plots 12.5 m apart. The species richness was 17 species in 9 genera and 12 families on all the sites investigated, with 11 species on the Kouré plateau, 13 on the Guittodo plateau and 17 in the Gorou Bassounga classified forest. Density was 234.79, 555.09 and 683.79 ind/ha, basal area 4.21, 7.2 and 8.62m2/ha and tree cover 19.8, 45.34 and 60.75¨%, respectively on these three sites. In terms of structure, the stand has a high proportion of relatively young individuals. Shannon's diversity (2.37 to 2.81 bits) indicates that the environments are of low diversity and Pilou's equitability (0.56 to 0.63) highlights a phenomenon of dominance in the three stands. The lowest similarity index (0.44) is obtained between the Kouré plateau and the Gorou Bassounga classified forest, and the highest (0.46) between the Kouré plateau and the Guittodo plateau. These results testify to the low diversity and young structure of this dying vegetation.*

***Keywords*— contracted vegetation, anthropic pressure, density, basal area, cover**

I. INTRODUCTION

The ecosystems of West Africa have undoubtedly been shaped by man for thousands of years (Wittig et al., 2002). The continuing degradation of vegetation cover is partly due to population growth and climatic factors (Wezel and Haigis, 2000). Anthropogenic influence on the evolution of vegetation is a source of threat to the survival of many useful species (Lykke et al., 1999; Hahn-Hadjali and Thiombiano, 2000) and locally accentuates the causes of ecological imbalance. This degradation of ecosystems and species richness is also one of the consequences of the arid climate (Thiombiano, 2005). Thus the drying up of the climate has led to a rapid transformation of ecological and social systems (Mahé and Paturel, 2009). This situation affects not only Sahelian regions, but also areas that are usually more humid (Grouzis and Albergel, 1989). In fact, natural resources are undergoing intense degradation as a result of physical, agro-climatic and/or anthropogenic factors (Rognon, 2007). Niger is no exception to this situation. It is prey to episodic droughts marked by the dieback of ligneous plants (Morou et al., 2016). This aridity is compounded by the devastating actions of man, particularly in contracted formations. Every year, an average of 60,000 ha of contracted forests on the plateaux of Niger are cleared (Ichaou, 2000). These forests are essential for local communities, which derive a large part of their economy from wood exploitation (Moussa et al, 2018). This degradation is manifested by changes in the floristic composition, structure and density of the vegetation (Bakhoum, 2013). The alternative to this degradation has been the introduction of regulatory provisions to protect forest land (Abdourhamane et al., 2013). Rural timber markets involving local people in management were set up in the 1990s to better organise and control logging. However, the high demand for wood energy resulting from strong population growth and the dysfunction of the management structures put in place have not enabled the trend to be reversed. It is clear that data on structure and diversity provide indicators for analysing trends in the qualitative and quantitative evolution of vegetation (Ouédraogo, 2006), and composition and structure vary considerably from one locality to another as a function of environmental factors and human disturbance (Blanc et al., 2000). Several recent studies (Morou, 2010, Lassina et al., 2011; Moussa et al., 2013; Diouf, 2012, José Luis et al., 2013; Rabiou, 2016, Idrissa et al., 2019) have been carried out in the zone, but their general nature does not allow us to specify the diversity and parameters of the vegetation.

II. MATERIALS AND METHODS

1.1 Study area

The study area corresponds to the Iullemenden basin located to the east of the River Niger, which encompasses the regions of Tillabéry, Dosso and the urban community of Niamey (Ichaou, 2000). They have a population of around 5,787,043 (INS, 2012) and are among the most densely populated areas of Niger. In this part of Niger, plateaux make up the bulk of the landscape, characterised by contracted plant formations. In places, there are shrub and tree savannahs and shrub steppes. Average annual rainfall varies from 350 mm in the extreme north (Kouré) to 800 mm in the extreme south (Gaya).

1.2 Choice of study sites

In order to better characterise this vegetation, three (3) sites were chosen according to a North-South climatic gradient and a decreasing degree of anthropisation (Figure 1). These sites were chosen on the basis of the existence of contracted vegetation on the plateau, the degree of anthropisation and their location along a rainfall gradient. The Kouré plateau, highly anthropised, located in the rural commune of Kouré (Tillabéry) at latitude 13°19′35″ N and longitude 2°37′15″ E. The Guittodo plateau, less anthropised than Kouré, is located in the rural commune of Farey (Dosso) at latitude 12°31'45"N and longitude 3°15'07"E. The Gourou Bassounga classified forest, which is less anthropised than the first two sites, is located in the extreme south-west of Niger, towards the Niger-Benin border at latitude 11°58′04″N and longitude 3°22′48″ E, part of which is in the commune of Gaya and the other in that of Tanda.

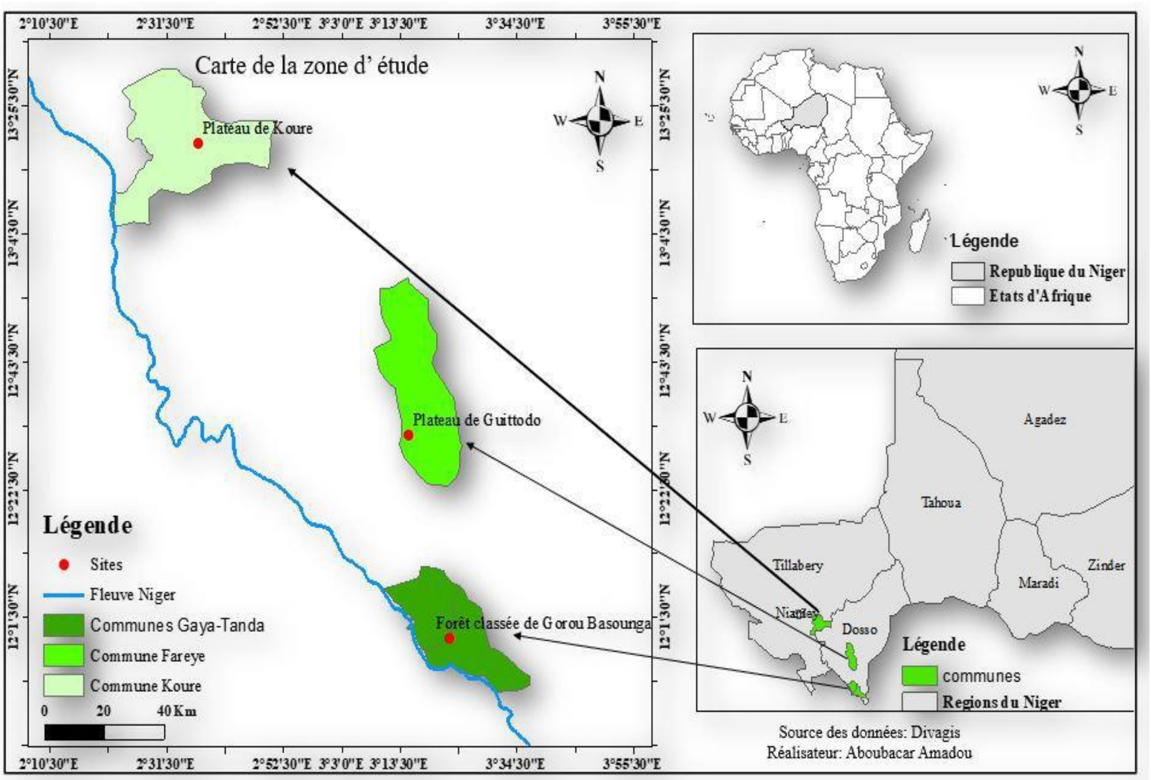

Fig.1: Location of study sites

1.3 Installation of the inventory system

Floristic surveys were carried out using the system proposed by Couteron et al. (1995) and recommended by the proceedings of the Niamey workshop for the inventory of contracted formations (SUN-UE, 2008). This system (Figure 2) respects the spatial configuration of the patterns of contracted formations. A pattern comprises a bare strip and a strip of vegetation with each sub-unit. The bare strip comprises parts: a= upstream and b= downstream of this bare strip and the vegetation strip comprises parts: c= an upper fringe or settling zone, d= furrow and e= lower fringe or snag fringe (SUN-UE, 2008).

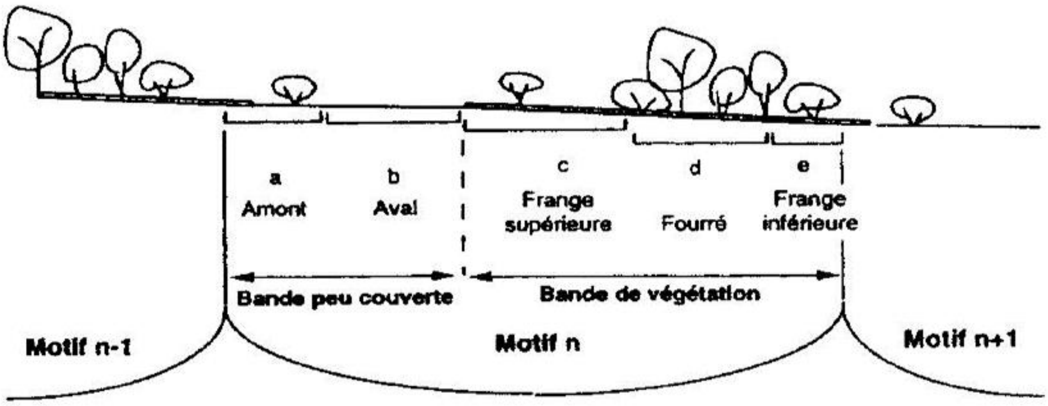

Fig.2: System proposed by Couteron et al in 1995 (SUN-UE, 2008)

1.4 Collection of inventory data

The data were collected in October and November 2021, corresponding to the start of the dry season. During this period of the dry season, when the herbaceous plants begin to dry out, the woody plants are still in full leaf (Fournier, 1991). It is therefore the most favourable period for collecting data on woody plants. Sampling was based on random transects, which according to (Gounot, 1969) allow the greatest diversity of the environment to be taken into account. On each site, five (5) transects were chosen at random. These transects are parallel and follow the steepest slope, with variable lengths depending on the natural spacing of eight successive wooded strips previously fixed per transect. Rectangular plots measuring 100mx25m were placed in the vegetated strips and arranged perpendicular to them to take into account variation in woody density (Thiombiano et al. 2016). Eight (8) plots were placed per transect at a rate of 40 plots per site, for a total of one hundred and twenty (120) plots. To facilitate data collection, the 2500m2 plots were subdivided into 12.5m x 12.5m plots as recommended by (SUN-UE, 2008) for contracted formations. A total of 640 plots were used to collect dendrometric data on each site. For the diameter measurements, the minimum exploitable diameter was taken into account, which is 4cm for contracted formations. Diameter measurements (<4m) are considered as belonging to regeneration (SUNU 2008). Measurements were taken of adult ligneous trees of all species. Heights (<7m) were measured using stakes and heights (>7m) using a Suunto clinometer. Trunk diameters were measured at 1.3 m using a forestry compass and/or caliper (Photo 1). The diameters of the crown on two (2) perpendicular axes were measured using a tape measure.

Photo 1: Height and diameter measurements of woody plants

1.5 Data analysis and processing

The density, which is the ratio of the total number of adult individuals in the sample (N) to the area sampled (S) per hectare, was calculated using the formula: D= N/S where N = total number of trees in the plots and S = area sampled (Ngom et al., 2013);

Total species richness (S) is the total number of species in the stand considered in a given ecosystem (Ramade, 2003).

The average species richness corresponds to the average number of species per survey for a given sample (Ramade, 2003);

Basal area was calculated as the tree area assessed at the base of the tree trunk using the formuler: $G=\frac{\Pi}{40000XS}\sum_{i=1}^{n} di^2$ (Rondeux, 1999), where S= plot area and di = diameter of trunk i at 0.3 m ;

The Lorey height (HL) is the average height of the individuals weighted by their basal area and is obtained by the formuler, $HL=\frac{\sum_{i=1}^{n} gi*hi}{\sum_{i=1}^{n} gi}$, where $gi= \frac{\Pi}{4}\, di^2$ (Rondeux, 1999);

Cover was calculated as the area of the tree crown projected vertically to the ground obtained by the formuler = $\frac{\sum \pi(\frac{d_{mh}}{2})^2}{S_E}$, where dmh = average crown diameter in m; S_E = sample area in hectare (Ngom et al., 2013).

The Shannon-Weaver Diversity Index (H) was calculated using the formuler $H=\sum_{i=1}^{s} pi \log_2 pi$, with Pi = ni/N, where Pi=frequency of the species (i); ni =number of individuals of the species, s=total number of species and N=total number of individuals (Rondeux, 1999). Diversity is low when H is less than 3 bits, medium if H is between 3 and 4 bits, and high when H is greater than or equal to 4 bits (Frontier and Pichod, 1995).

Pielou equitability is calculated using the formuler: **E=H/Hmax,** where H is Shannon's diversity index and Hmax is the maximum diversity index. If E ∈ [0 -0.6] then Piélou equitability is low (dominance phenomenon existing in the community). If E ∈ [0.7 -0.8] then Pielou's equitability is average. If E ∈ [0.8 -1] then Pielou equitability is high (absence of dominance in the community) (Garba et al, 2017).

The Sorensen Index is calculated using the formuler K = 2C / (2C + A + B), where A= number of species from list a (site A), B= number of species from list b (site B), C= number of species common to both sites (A and B) (Thiombiano et al. 2016).

The Family Importance Value Index (FIV) is calculated using the formuler FIV = relative dominance + relative density + relative diversity. All the information gathered on the families is included in this index. It provides information on the floristic importance of each family, the number of individuals in the family out of the number of species in the family and the quantitative importance of the family in terms of basal area. It is the sum of three factors representing the quantitative biometric value of the survey per hectare (Mori et al 1985).

The Species Importance Value Index (IVI) is a synthetic and quantified expression of the importance of a species in a stand. It provides a better appreciation of the importance of species in a plant community. The SVI is defined as the sum of relative dominance (Domr), relative frequency (Fr) and relative density (Dr), which are calculated using the following formuler:

IVI = Domr + Fr + Dr (Baggnian et al., 2019), with:

$$Domr = \frac{\text{Total basal area of species}}{\text{Basal area of all species}} \text{ x } 100$$

$$Fr = \frac{\text{Species frequency}}{\text{Sum of species frequencies}} \text{ x } 100$$

$$Dr = \frac{\text{Number of individuals of the species per ha}}{\text{Total number of individuals per ha}} \text{ x } 100$$

These three factors vary between 0 and 100%, while the IVI, which corresponds to the sum of the three factors representing the quantitative biometric values of the species, varies between 0 and 300% and highlights the most important species. Species with an IVI ≥ 20% are those ecologically important (Traore et al, 2012) and were retained as dominant and their demographic trend was established. Stand structure: The theoretical Weibull distribution was used because of its great flexibility of use and presents a great variability of forms according to the values taken by its theoretical parameters (Bullock, 2005). It has three parameters (position a, scale or size b and shape c and its probability density function f (x) is: $F(x) = \frac{c}{b}(\frac{x-a}{b})^{c-1} \exp(-(\frac{x-a}{b})^c)$. Parameter a corresponds to the threshold value which is the smallest diameter value; parameter b is linked to the central value of the diameter class distribution and parameter c to the observed structure which, depending on its value, leads the Weibull distribution to take several forms. A test of the fit of the observed distribution to the theoretical Weibull distribution (Rondeux, 1999) was carried out using Minitab 16 software.

III. RESULTS

2.1 Species richness

Species richness is one of the main characteristics of a plant stand and is the measure most frequently used to study woody plant biodiversity. The species richness was (17) species, distributed between 9 genera and 12 families over all three sites investigated. It increases along the rainfall gradient, with (11) species on the Kouré plateau, (13) on the Guittodo plateau and (17) in the Gorou Basounga classified forest, which is home to all the species inventoried. The average species richness was 4.70 species for the study area, with 3.4 in Kouré, 4.77 in Guittodo and 5.95 in Gorou Bassouga. The variance in mean species richness was 2.77 in the study area, with 1.14 in Kouré, 2.3 in Gorou Bassounga, and an intermediate value of 1.63 in Guittodo, indicating an increase along the rainfall gradient (Table 1).

Table 1: Variation in specific richness

Parameters	Koure Plateau	Guittodo Plateau	Gorou Bassounga Forest	Study sites
Specific richness (S)	11	13	17	17
Mean species richness (s)	3,4	4,77	5,95	4,70
Variance of (s)	1,14	1,63	2,30	2,77

2.2 Comparison of dendrometric parameters

The results (Table 2) show that the values of all the parameters examined increase with the rainfall gradient and decrease with the level of human settlement. Overall analysis of the results shows that there is a significant difference (P<0.05) between the different sites (photo1) for density, diameter, Lorey height (HL), basal area and crown cover.

Table2: Results of multiple comparison tests of the means of dendrometric parameters according to sites

Dendrometric parameters	KP	GP	GBCF	Probability
Density (Individuals/ha)	234,79±23,9^{b}	555,09±21^{b}	683,79±23,3^{a}	< 0,040
Average diameter (cm)	3,11±2,02^{a}	3,67±2,6^{a}	6,57±4,3^{b}	< 0,040
Average height at Lorey (m)	2,51±1,6^{a}	3,26±1,8^{b}	4,70±2,2^{b}	< 0,021
Average basal area (m²/ha)	4,21±3,1^{a}	7,2±4,6^{b}	8,62±1^{a}	< 0,031
Recovery (%)	19,8±58,1^{a}	45,34±58,9^{b}	60,75±75,1^{a}	< 0,035

kP=Kouré plateau, GP=Guittodo plateau, GBCF= Gorou Bassounga classified forest

The same letters on the same line mean that there is no significant difference between the averages, while different letters mean that there is a significant difference between the averages.

Photo1: View of contracted vegetation (A=Kouré plateau, B=Guittodo plateau, C=Gorou Bassounga classified forest)

2.3 Height structure

Analysis of height class structures (Figure 3) shows that on the Kouré and Guittodo plateaux, woody vegetation is distributed in only three classes [1-3 m [, [3-5 m] and [5-7 m]. However, there is a predominance of individuals in the [1-3 m] class, followed by the [3-5 m] class and a very low representation of individuals in the [5-7 m] class, although densities are higher in Guittodo than in Kouré. The Gorou Bassounga classified forest has a more diverse distribution, with a predominance of individuals in the [3-5 m] class.

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This is followed by the smallest class [1-3 m] and then the [5-7 m] class. We also note the appearance of three new classes [7-9 m [, [9-11 m [and [11-13 m [which are very poorly represented.

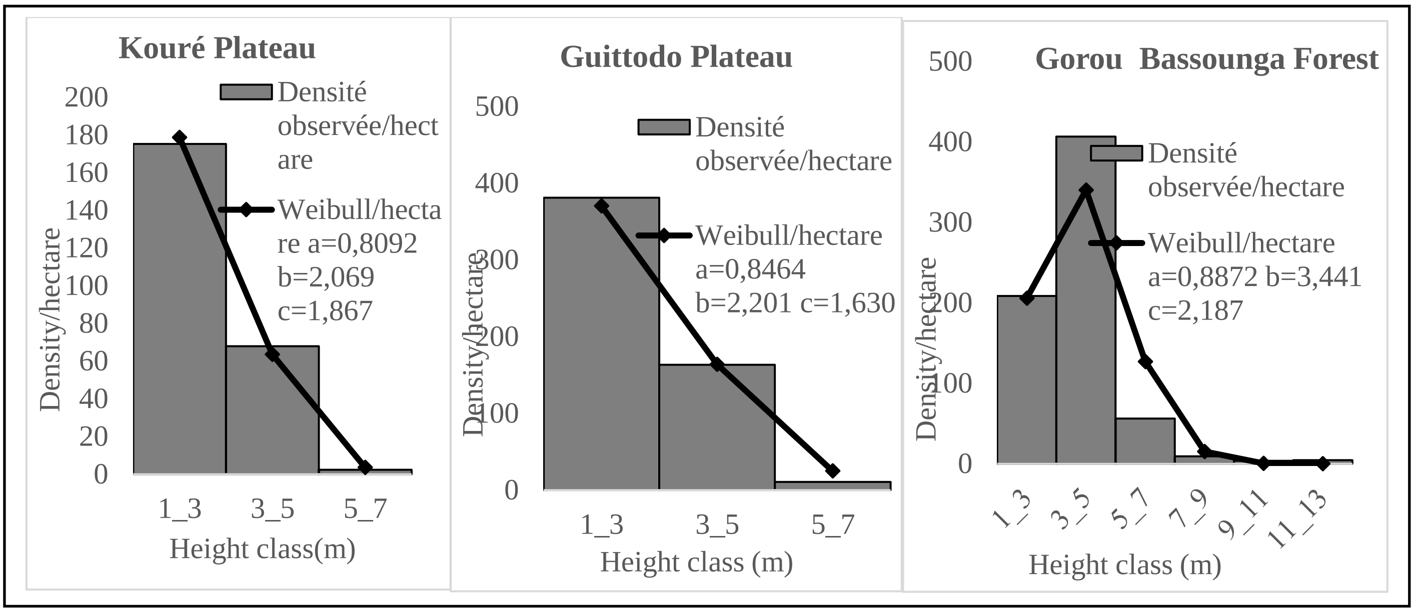

Fig.3: Height structure of the stands on the three study sites

2.4 Diameter structure

The diameter class structures of the three sites show an "inverted J" shape, with a shape parameter c of less than 1 (Figure 4). This situation is characteristic of stands with high regeneration potential. At all three sites, individuals in the [4-8cm] class predominate. This is followed by the [8-12cm] and [12-16cm] classes, with densities increasing with the rainfall gradient. The Gorou Bassounga forest is predominant, followed by the Guittodo plateau. The [16 - 20cm] class is very sparsely represented in Kouré and Guittodo. The [20 - 24cm] class is virtually unrepresented in Kouré, but is represented by rare individuals in Guittodo. The other classes [24 - 28cm [and [28 - 32cm] are represented by a few rare individuals in Guittodo.

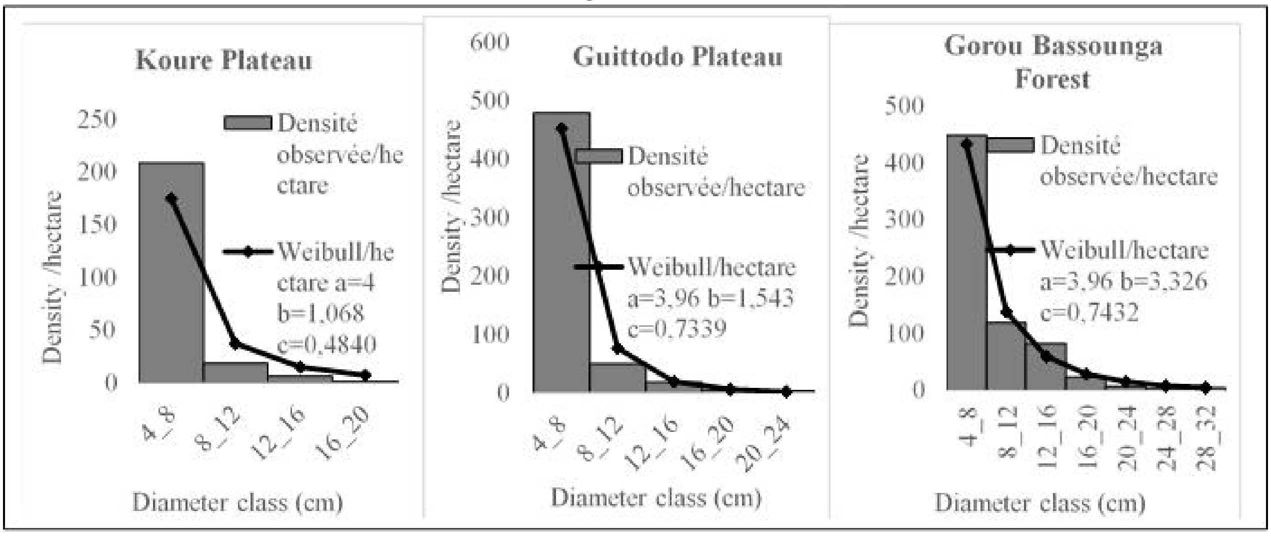

Fig.4: Diameter structure of the stands on the three study sites

2.5 Diversity indices

Analysis of the results (Table 2) shows that Shannon diversity and Pielou equitability are 2.64 bits and 0.95 respectively in the study area. Diversity is 2.37 bits on the Kouré plateau, 2.73 bits on the Guittodo plateau and 2.81 bits in the Gorou Bassounga classified forest. These values of less than 3bits indicate that the environments are of low diversity. Pielou's equitability of 0.56 at Kouré, 0.58 at

Guittodo and 0.63 at Gorou Bassounga indicates dominance in these three stands.

Table 3: Shannon diversity index and Pielou equitability

Parameter	KP	GP	GBCF	Study sites
Shannon diversity (H)	2,37	2,73	2,81	2,64
Pielou equitability (E)	0,56	0,58	0,63	0,95

The lowest similarity index (0.44) was obtained between the Kouré plateau (Sahelian zone) and the Gorou Bassounga classified forest (northern Sudanian zone) and the highest index (0.47) between the Kouré plateau and the Guittodo plateau (Sahelo-Sudanian zone).

Table 4: Sorensen indices between study sites

Sites	Koure Plateau	Guittodo Plateau	Gorou Basounga forest
Koure Plateau	1	0,47	0,44
Guittodo Plateau		1	0,46
Gorou Bassounga forest			1

2.6 Family Importance Value Index (FIV)

Analysis of the floristic characteristics showed a predominance of five families on the study sites. These are, in order of numerical importance, the Combretaceae, Caesalpiniaceae, Rubiaceae, Tiliaceae and Fabaceae families. On the Kouré plateau, the Combretaceae, Caesalpiniaceae and Mimosaceae families dominate in this order, and the Combretaceae, Mimosaceae and Fabaceae families in Guittodo. The classified forest of Gorou Bassounga is dominated by the Combretaceae family, followed by Caesalpiniaceae and Rubiaceae. However, there is a decrease in the representation of Combretaceae along a rainfall gradient and a relative presence of other species depending on the site (table4).

Table 4: Index of importance of families by site.

Family	K Plateau	G Plateau	GB forest	Study Sites
Combretaceae	292,31	287,83	243,08	261,26
Caesalpiniaceae	6,58	0,73	32,18	20,48
Rubiaceae	0,36	1,07	6,07	3,85
Tiliaceae	0,00	0,00	5,04	3,11
Fabaceae	0,00	3,38	3,50	3,05
Capparidaceae	0,00	0,34	3,01	2,01
Mimosaceae	0,75	6,65	0,41	1,97
Olacaceae	0,00	0,00	3,06	1,87
Euphorbiaceae	0,00	0,00	2,02	1,30
Anacardiaceae	0,00	0,00	1,63	1,10
Total	**300**	**300**	**300**	**300**

2.7 Species Importance Value Index (IVI)

Analysis of the results (table 5) shows that Combretum micranthum is the most represented species in the three taken together. It is followed by Combretum nigricans, Guiera senegalensis and Combretum glutinosum. In fact, on all three sites, this species has the highest index, but it decreases along the rainfall gradient. At Combretum nigricans and Combretum glutinosum, the variation in this index does not follow the rainfall gradient. The dominant IVI species ≥ 20% (Traoré et al., 2012) are Combretum micranthum, Combretum nigricans, Guiera senegalensis, Combretum glutinosum and Cassia sieberiana. The other species have low or zero indices. Among the latter, we can distinguish those with a zero index at one site (Acacia macrostachya and Boscia angustifolia) or at two sites (Grewia flavescens).

Table 5: Importance indices for the most represented species

E Species spèces	K Plateau de	G Plateau	GB Forest	Sites
Combretum micranthum	140,15	121,52	89,72	105,99
Combretum nigricans	50,43	100,13	86,52	82,70
Guiera senegalensis.	95,15	63,36	15,10	39,24
Combretum glutinosum	7,07	4,08	49,25	31,86
Cassia sieberiana	6,60	0,73	31,28	20,48
Gardenia Sokotensis	0,36	0,24	6,54	3,85
Grewia flavescens	0,00	0,00	5,14	3,11
Acacia macrostachya	0,00	3,38	3,49	3,05
Boscia angustifolia	0,00	0,34	3,01	2,01
Acacia ataxacantha	0,75	1,65	0,41	1,97
Total	300	300	300	300

The factorial correspondence analysis (fig. 5) used to better elucidate the interactions between the sites and the species they shelter reveals that the two axes alone concentrate 99.9% of the data, axis 1 with 81.7% and axis 2 with 18.2%. The factorial plan shows that the presence of a species is linked to the specific characteristics of each site. The Kouré plateau, which receives less water and is more anthropised, is characterised by two species, while the Guittodo plateau, in an intermediate situation, is characterised by three species. The Gorou Bassounga classified forest, located in the more watered and less developed northern Sudanian zone, stands out with eight species characteristic of the northern Sudanian climate.

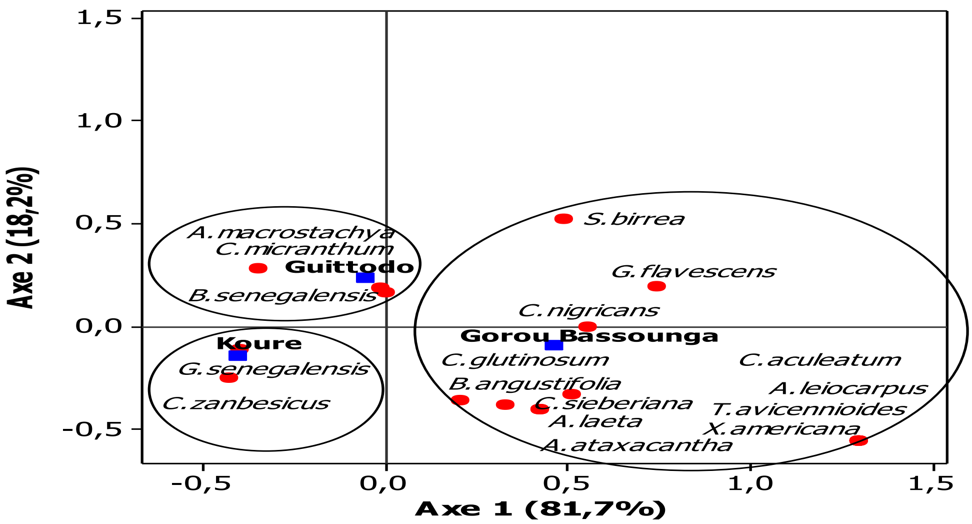

Fig.5: Distribution of characteristic species by site

IV. DISCUSSIONS

4.1 Floristic composition and vegetation structure

The results reveal that the flora of the wooded strips of contracted vegetation is rich in seventeen (17) species distributed in twelve (12) genera and nine (09) families, with a variance in mean species richness that decreases with the degree of anthropisation and increases with the rainfall gradient. According to Ngom (2013), the higher the variance of mean species richness, the greater the heterogeneity of the stand. Our results indicate the influence of human pressure on the heterogeneity of contracted plant formations. This human influence on the heterogeneity of a plant stand has also been reported by (Ngom, 2013). The rainfall regime has a positive effect on these parameters, which decrease when humans are more present. The extreme case of the Kouré plateau can be explained by the more arid climate and the massive exploitation of wood to supply the towns of Niamey and Dosso. These variations show that climate and man shape the physiognomy of this vegetation and confirm (Ambouta, 1997) who deduced that forest resources in Niger are under climatic and socio-economic pressure.

Average diameter, Lorey height, basal area and tree cover are higher in the Gorou Bassounga classified forest. This can be explained by the fact that the flora contains a few large trees with large trunks and broad crowns as a result of the low human presence and more favourable climatic conditions. These results confirm those of Akpo (1993), who reports that large trees with large crowns contribute more to tree cover and, to a certain degree, modify local ecological conditions. The cover of the Kouré plateau (19.80%) is much lower than those obtained by (Ichaou 2000) in the contracted formations of Dingazi, Kouré and Banizoumbou, which vary from 30.09% to 79.20%. On the other hand, the recoveries obtained at Guittodo (45.34%) and Gorou Bassounga (60.75%) confirm those obtained by Ichaou. In fact, basal area and cover remained low despite high densities. This can be explained by the fact that the flora is dominated by combretaceae, which are shrubs with small trunks and smaller crowns. This confirms Bouxin (1975), who maintains that there is not always a parallel between basal area, crown cover and density.

4.2 Vegetation structure

The Weibull height structure shows an asymmetrical distribution dominated by young trees, which make up the majority of the trees inventoried at the three sites. This reveals the importance of the shrub layer. The Kouré and Guittodo plateaux are dominated by the [1-3 m] class, followed by the [3-5 m] class, with very little representation of the [5-7 m] boundary class. This situation can be explained by the massive exploitation of large trees, the abrupt break in the curves of which characterises formations weakened by harvesting. Our results are more alarming than those of Ichaou (2000), who also reported the weakening of these formations due to harvesting. This shows the increasing degree of anthropisation over time. In the Gorou Bassounga classified forest, the distribution is dominated by the [3-5 m] class, followed by the [1-3 m] and [5-7 m] classes. We also note the presence of trees in the higher classes [7-9 m [, [9-11 m [and [11-13 m], which are very poorly represented, indicating a dying stand of large trees. The presence of large trees and the dominance of small and medium-sized trees give this vegetation the attributes of a more complete structure, but one that requires safeguarding. These facts are linked to a lower level of anthropisation and more favourable climatic conditions reported by (Rabiou, 2016) in the Gorou Bassounga classified forest and the W Park in Niger. The shape parameters are between 1 and 3.6, of which 1.63 at Guittodo and 2.18 at Gorou Bassounga are characteristic of stands more or less impacted by exogenous actions.

The weibull diameter structure shows inverted J distributions, similar in shape across the different sites. The highest shape parameters are observed in the Gorou Bassounga classified forest, followed by the Guittodo plateau and finally the Kouré plateau. These findings can be explained by the fact that the Kouré site is highly anthropised because of its proximity to the capital Niamey and the town of Dosso. The high demand for wood in these major towns has led to excessive logging to satisfy ever-increasing needs. The Guittodo plateau has higher densities, reflecting a lower level of human activity and more or less favourable climatic conditions. In recent years, however, the gradual establishment of camps trying to make their homes in the areas from which they fled, fleeing insecurity, has accelerated the destruction of this vegetation due to the uncontrolled exploitation of large-diameter timber. This situation highlights the link between the degradation of natural resources and insecurity, which could deal a severe blow to the structure of the vegetation if urgent measures are not taken. The case of the Gorou Bassounga classified forest reflects that of a site with little human activity, characterised by the presence of certain large-diameter trees. This situation can be explained by the low demand for firewood compared with the first two sites. As the site is in the northern Sudanian zone, the more favourable climatic conditions, combined with the low level of human activity, justify the presence of large-diameter trees. Husch et al. (2003) report that a correct interpretation of the structure of a stand requires above all a good fit between the observed shape and a theoretical distribution. The values of the shape parameter c, linked to the diameter structure on the three sites investigated, the Kouré plateau (0.4840), the Guittodo plateau (0.7339) and the Gorou Bassounga classified forest (0.7432), are less than 1. These values of less than 1 indicate an inverted J-shaped distribution, characteristic of multi-species stands in which the number of large-diameter trees is decreasing (UNDESERT, 2016). These results are similar to those obtained by (Ichaou, 2000; Rabiou, 2026), who reported the regression of large-diameter trees in the contracted formations of western Niger.

4.4 Species diversity indices and ecological importance

The Shannon diversity indices show that plant diversity is low both for the study area as a whole and at the various sites, with an increase along the rainfall gradient. This variation is linked to the adaptation of certain species to a more humid environment, to the physico-chemical properties of the soil, to the reduction in human pressure, but also to the conservation actions undertaken in the classified forest. These results corroborate those of certain authors who maintain that the variation in plant diversity between zones depends on rainfall (Neya et al., 2018; Abasse al., 2019), population density (Larwanou et al., 2012; Massaoudou et al 2015; Garba et al 2017) and edaphic conditions in these zones. The very low value on the Kouré plateau can be explained by the drier climate and the strong human presence. Pielou's equitability indices also increase with the rainfall gradient. The low values of the Pielou equitability index in the three sites indicate a phenomenon. Species from the Combretaceae family, which are characteristic of arid climates, dominate the other species and consequently colonise the environment. In the Gorou Bassounga forest, the dominance of Combreataceae is not sufficiently pronounced due to climatic and human conditions that are more favourable to the emergence of species. The value of the Sorensen index shows the existence of species common to all three sites. The similarity is stronger between the Kouré and Guittodo plateaux, which belong to the same agro-ecological zone, but with differences in annual rainfall totals. The lower similarity between the Kouré plateau and the Gorou Bassounga classified forest can be explained by their appearance in two different agro-climatic zones. The Family Importance Value Indices show that Combretaceae dominate all the areas surveyed, even in the driest zone. These results confirm (Savadogo et al., 2016), who report that droughts in the Sahel have led to a natural selection of the hardiest species, similar to that of the Combretaceae family. This means that this family is better adapted to harsh environmental conditions (Sreetheran et al., 2011). This predominance of Combretaceae has been observed by (Ouédraogo, 2006, Bognounou et al., 2009, Froumsia et al., 2012) who found similar results respectively in western Burkina Faso in the sectors (northern Sahelian, southern Sahelian, northern Sudanian and southern Sudanian) and in the Kalfou forest reserve in Cameroon. The decrease in the frequency of Combretaceae with the rainfall gradient can be explained by the xerophytic nature of the species, as reported by Aubreville (1950). Other authors (Rabiou, 2016; Abasse et al., 2019) link the decrease in the proportion of Combretaceae from the strict Sahelian zone to the northern Sudanian zone to rainfall. They are indicative of a dry climate (Rabiou, 2016) and can extend their roots as far as the water table to satisfy their water needs (Abdourhamane et al. 2013). The low representation or absence of certain families on certain sites is justified by their low capacity to adapt or not to the local conditions characteristic of these sites. Correspondence factorial analysis revealed Guiera senegalensis and Croton Zambeisicus as characteristic species of the Kouré plateau, Acacia macrostachya, Combrethum micrathum and Bossia senegalensis for the Guittodo plateau and eight species for the Gorou Bssounga classified forest. This reflects the greater presence of these species on the latter site, where local conditions (climate, soil and human pressure) are more favourable. (Ambouta, 1997 and Ngom, 2013) describe these characteristic species as good indicators of changes in the state of woody vegetation. Our results confirm those of Aubreville (1950), who reports that the distribution of woody species is strongly conditioned by their xerophilic or hygrophilic characteristics, and those of Charahabil (2013), who also links it to anthropogenic pressure. In this context, many woody species are regressing in favour of a few more resilient species.

V. CONCLUSION

This study shows that the floristic composition and structure of contracted vegetation are dependent on both rainfall and human pressure. They evolve along the North-South rainfall gradient and decline with the level of human activity. The Kouré and Guittodo plateaux are characterised by a stand dominated by small and medium-diameter shrubs. Large-diameter trees are absent from Kouré and are very poorly represented on the Guittodo plateau. This is an indicator of a growing human presence. In the Gorou Bassounga forest, there are a few large-diameter trees, indicating a less pronounced level of human activity. Combretaceae predominate on all the sites investigated, with proportions decreasing with the rainfall gradient. Statistical analysis of dendrometric parameters shows significant differences along this gradient. The results of this research contribute to a better understanding of the current state of the floristic composition and structure of this characteristic vegetation of western Niger, with a view to better preserving the species that are subject to strong climatic and human pressures.

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