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Biodiversity change as a human impact gradient in the biosphere reserve of Ferlo (Northern Senegal)

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ABSTRACT:

The present study aims to investigate the biodiversity of woody vegetation along a gradient of human impacting region in the three constituent parts of Ferlo Biosphere Reserve (FBR): the core area, the buffer zone and the transition area. We conducted an inventory of 110 plots of 900 m² each. Total species richness was 49 species distributed in 32 genera within 16 botanical families. The analysis of contesimal frequency showed that *Guiera senegalensis* is the most common species with a presence of 75% of such records. Examination of species abundance spectrum showed that four most abundant species such as *Guiera senegalensis* (29.5%), *Combretum glutinosum* (15.9%), *Pterocarpus lucens* (11.6%) and *Boscia senegalensis* (10 , 5%). These four species represent 68% of the total individuals of the RBF and are also the four most common species. The spectrum of abundance of families showed that *Combretaceae* is the best represented family with almost half of the number of species (49.7%). The representativeness of biological types and geographical affinity of the species has been established for the woody vegetation in the study area. The study of diversity indices revealed that the buffer zone and the transition area are subjected to multiple uses and experiencing human action. It has a greater diversity and a level of organization with higher timber stand than the central area which is an integral conservation zone.

Keywords:
Biosphere reserve - diversity - flora - abundance

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INTRODUCTION

Biosphere reserves are the areas of terrestrial and coastal / marine ecosystems that promote solutions to reconcile the conservation of biodiversity with its sustainable use (UNESCO, 1996). In addition to their function of conserving biodiversity, biosphere reserves contribute to sustainable human development through the provision of ecosystem services. To fulfill its multiple functions, the Ferlo biosphere reserve has a core area, a buffer zone and a transition area. The central area has a legal status ensuring the long term protection of landscapes, ecosystems and species it contains. It is large enough to meet the objectives of conservation and is the least anthropized area. The buffer zone surrounds or adjoins the core area. This area is the place to research the development of natural vegetation management methods, farmlands, forests, fisheries etc., to qualitatively increase production while ensuring the fullest extent possiblity, maintaining natural processes and biodiversity. The transition zone is the location with high land use and settlements area where human inhabitations is maximum; this is the most anthropized zone (Ngom, 2013).

The human impact is the result of human actions leading to depletion and ecosystem degradation (Bournérias, 2001) at increasing rates in the transition zone, buffer zone and core area.

The Ferlo Biosphere Reserve (FBR) consists of a set of ecosystems of great diversity. The biodiversity of a population is a result of combination of three aspects such as species richness, evenness of distribution or abundance and species composition (Gosselin and Laroussinie, 2004); this is mainly due to anthropization. Thus, the study of the floristic richness in different areas of the biosphere reserve is an important indicator of biodiversity; it does explain the diversity alone, focussing on the diversity indices at equitability and species composition of plant communities.

To better understand the variability in biodiversity in the various component parts of the biosphere reserve, we began to examine the taxonomic richness, the phytogeographical affinities, the biological types, indices of diversity and similarity, equitability and composition taxa.

MATERIALS AND METHODS

The study area

The study was conducted in the Ferlo Biosphere Reserve in the northern part of Senegal between 14° 24 '- 16° 11' N latitude and 13° 07'- 14° 51 'W longitude. Biosphere Reserve of Ferlo which spans 2,058,214 hectares mainly has three functions (biodiversity conservation, economic development and sustainable human and knowledge production) and operates it in three inter-connected areas (Figure 1).

The climate is dry tropical, Sudano-Sahelian type, characterized by rains that extend from June to October to conventionally distinguish two periods in a year: a dry season ($P < 0.35$ FTE) 7 to 9 months (October to May) and a rainy season ($P \geq 0.35$ FTE) from 3 to 5 months.

Rainfall data from the reference station Ranerou showed that the average precipitation over 51 years (1960-2011) is 474 mm / year for 29 days of rain on average (Figure 2). The wettest year of the observed series is 1969 with 845 mm of rain for 36 days. However, the two most deficit years are 1983 (254 mm) and 1971 (275 mm). These two years correspond to the two major droughts in the Sahel.

The annual average temperature is 28.6°C but with high thermal amplitudes, the average values of minimum and maximum monthly temperatures are 17°C, (December) and 43°C (May) respectively.

Vegetation surveys

The zoning map of the biosphere reserve is the sampling frame. The sampling is used in the transect method. A total of seven West to East (WE) orientation transects of different lengths each 4 km away were randomly selected. Point statements are identified in the field using a GPS. Throughout the FBR, 110 surveys were sampled including 57 core areas, 28 buffer zones and 25 transition areas. The sampling unit is a square plot of 30 mx 30 m or a raised area of 900 sqm (Boudet, 1984) for the study of the Sudano-Sahelian vegetation.

In each survey, an exhaustive inventory of wood vegeation was observed. Dendrometric measurements were performed to evaluate some dimensional parameters: circumference at the base of the trunk to 30 cm from the ground, the diameter of the projection of the crown to the ground and tree height.

Botanical samples are identified in the field or in the laboratory using the Flora of Senegal (Berhaut, 1967) and the book 'Trees, shrubs and West African lianas' (Arbonnier, 2000). Synonyms have been updated and standardized on the basis of the list of plants and flowers of Tropical Africa (Lebrun and Stork, 1991, 1992, 1995, 1997).

Data processing

The data collected from vegetation surveys were processed using Microsoft Excel and XLStat softwares. These softwares made us to study the species richness, frequency analysis and taxonomic diversity of woody plants present in the Ferlo Biosphere Reserve.

Taxonomic composition

The composition of the woody plant were studied by looking at the number of categories identified in the same taxonomic level (species, genera and families). Total species richness (S) which is the most commonly used indicator to study biodiversity is the total number of species that includes the population considered in a given ecosystem (Ramade, 2003).

The abundance of species and families

In this study, we have calculated the probability of occurrence of the species (pi). If in a given stand, 'nor' is the number of individuals of a species '*i' and* 'N' the total number of individuals that

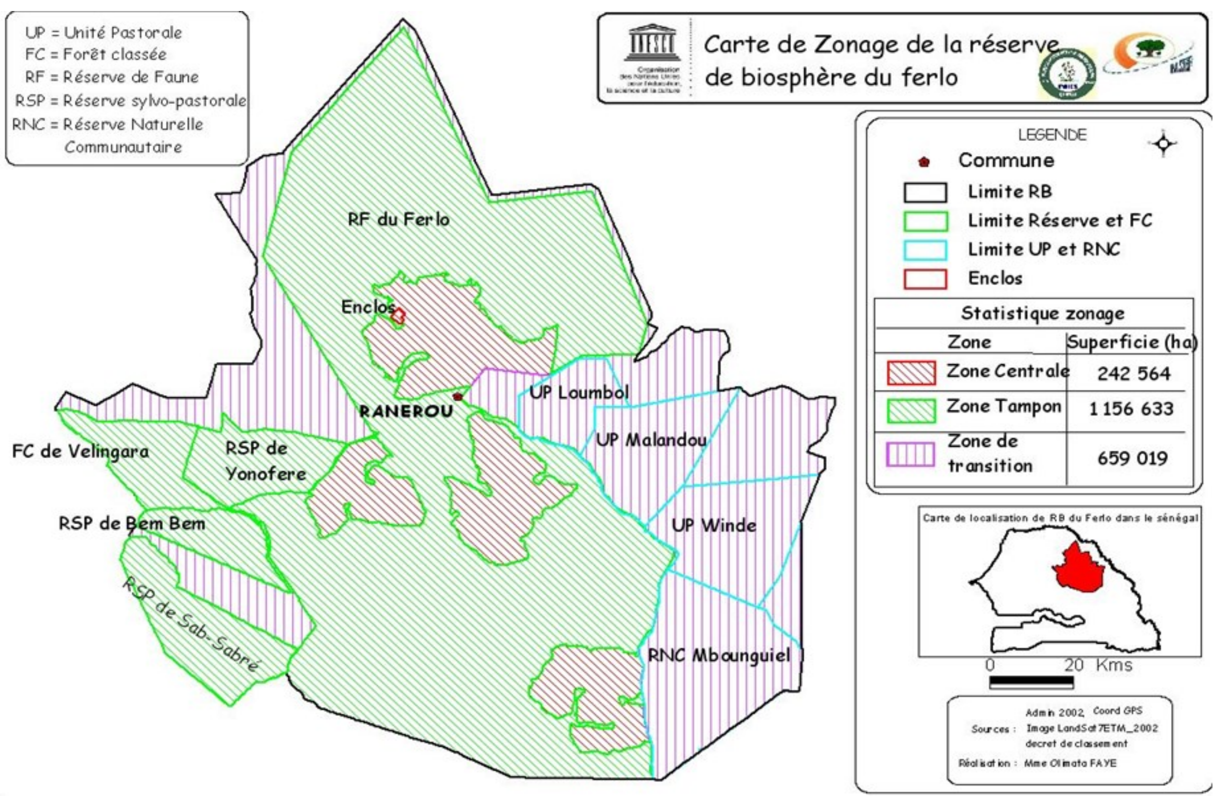

Figure 1. Showing the Zones Map of the biosphere reserve of Ferlo

includes the settlement, we have the following formula (Ramade 2002).

$$pi = \frac{ni}{N}$$

The biological types

The biological types are the species index of an environment. The biological types are ascertained by their distribution and reflection in the environmental conditions of a region (Mahamane, 2005). Raunkier system (1934) was used to distinguish the woody group phanerophytes in 4 types:

- The microphanerophytes: their woody stems exceed 8 m in height
- The mesophanerophytes: their woody stems are between 2 and 8 m in height
- The microphanerophytes: their woody stems are between 0.5 and 2 m in height
- The nanophanerophytes: their woody stems do not exceed 0.5 m in height.

Phytogeographic affinities

Regarding the phytogeographical affinities, we have identified four types of species inventoried in the memberships based on previous work in the West African region (Chevalier, 1938; Achigan, 2002; Ndanikou, 2006; Arbonnier, 2002). These types are:

- The species of Sahelian affinity
- The species of Sudano-Sahelian affinity
- The species of Sudanese affinity
- The species of Sudano-Guinean affinity

Diversity indices

Diversity indices were calculated for three zones and across the biosphere reserve; the diversity index used were Shannon diversity index (H'), evenness index (E), Gleason diversity index (G) and Simpson diversity index (D).

The Shannon Weaver diversity index (H'), which considers both the abundance and species richness, was well suited to the comparative study of the stands because it is relatively independent of the sample size (Ramade, 2003).

The Shannon-Weaver Index is expressed in bits and is given by the following formula:

$$H' = -\sum_{i=1}^{S} \frac{Ni}{N} \log 2 \frac{Ni}{N}$$

Where, 'Ni' = the number of species 'i'; N = total number of species.

This Shannon index is minimal if all individuals

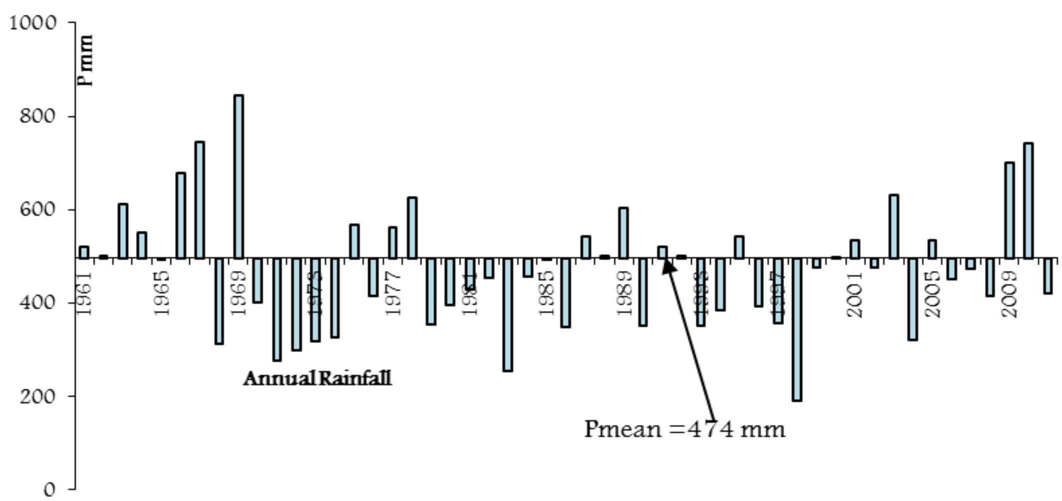

Figure 2. Analysis of the evolutionary trends of annual rainfall by the weighted moving average method

Table 1. List of different taxa and their relative importance in the Central Area (CA), the Buffer Zone (ZT) and the Transition Area (TA) the transition area (TA)

Species	Zones of RBF CA	ZT	TA	Genus	Family	Frequency of families in %
Acacia ataxacantha	X	X	X			
Acacia ehrenbergiana	X					
Acacia laeta		X	X			
Acacia macrostachya	X	X	X			
Acacia nilotica	X	X		*Acacia*	*Mimosoideae*	22.45
Acacia pennata		X	X			
Acacia raddiana			X			
Acacia senegal	X	X	X			
Acacia seyal	X		X			
Dichrostachys cinerea		X	X	*Dichrostachys*		
Entada africana		X		*Entada*		
Combretum aculeatum			X			
Combretum glutinosum	X	X	X			14.29
Combretum micranthum	X	X	X	*Combretum*	*Combretaceae*	
Combretum nigricans	X					
Anogeissus leiocarpa	X		X	*Anogeissus*		
Guiera senegalensis	X	X	X	*Guiera*		
Terminalia avicennioides		X	X	*Terminalia*		
Boscia angustifolia	X	X	X			
Boscia senegalensis	X	X	X	*Boscia*		
Cadaba farinosa			X	*Cadaba*		
Crataeva adansoni			X	*Crataeva*	*Capparaceae*	12.24
Maerua angolensis		X				
Maerua crassifolia	X			*Maerua*		
Pterocarpus erinaceus	X	X	X			
Pterocarpus lucens	X	X	X	*Pterocarpus*		
Piliostigma reticulatum	X			*Piliostigma*	*Caesalpinioideae*	8.16
Dalbergia melanoxylon	X		X	*Dalbergia*		
Mitragyna inermis	X			*Mitragyna*		
Feretia apodanthera	X	X	X	*Feretia*		
Gardenia erubescens	X				*Rubiaceae*	8.16
Gardenia ternifolia			X	*Gardenia*		
Adansonia digitata	X	X	X	*Adansonia*		
Bombax costatum	X			*Bombax*	*Bombacaceae*	4.08
Grewia bicolor	X	X	X			
Grewia flavescens	X			*Grewia*	*Tiliaceae*	4.08
Sclerocarya birrea	X		X	*Sclerocarya*		
Lannea acida	X	X	X	*Lannea*	*Anacardiaceae*	4.08
Calotropis procera	X		X	*Calotropis*		
Leptadenia hastata	X	X	X	*Leptadaena*	*Asclepiadoideae*	4.08
Ziziphus mauritiana	X				*Rhamnaceae*	
Ziziphus mucronata		X		*Ziziphus*		
Maytenus senegalensis	X		X	*Maytenus*	*Celastraceae*	2.04
Asparagus pauli-gulielmi			X	*Asparagus*	*Liliaceae*	2.04
Balanites aegyptiaca	X	X	X	*Balanites*	*Balanitaceae*	2.04
Commiphora africana	X	X	X	*Commiphora*	*Burseraceae*	2.04
Sterculia setigera	X	X	X	*Sterculia*	*Sterculiaceae*	2.04
Strychnos spinosa		X		*Strychnos*	*Loganiaceae*	2.04
Adenium obesum	X	X	X	*Adenium*	*Apocynaceae*	2.04
49	35	28	35	32	17	100

of the population belong to a single species; it is maximum when all individuals are distributed equally over all species (Frontier, 1983).

Evenness index

From the Shannon diversity index, we determined the evenness or equitability (E) Pielou**.** The value of this index ranges from 0 to 1. A high value of this index (that is nearer to 1) indicate that the population is homogeneous, or that individuals are fairly distributed between different species. By cons, when its value is low (that is to say close to 0), the population is dominated by one or a few species.

$$E = \frac{H'}{H\,max}$$

where, H = Shannon index; H $_{max = log}$ 2 S, 'S' being the total species richness.

Simpson's Diversity Index

Simpson's Diversity Index represents the probability that two individuals chosen at random in the studied population belong to the same species. It is given by the following formula:

$$D' = 1 - \Sigma \frac{Ni(Ni-1)}{N(N-1)}$$

where, Ni: number of individuals of the species and given 'N': total number of individuals.

The value of the index ranges from 0 to 1, the maximum diversity is represented by the value 1, and the minimum of diversity 0 (Schlaepfer and Bütler, 2004).

The gleason diversity index

The Gleason diversity index is based on the assumption of a logarithmic growth in the number of species recorded as 'S', based on the number 'N' of individuals that are examined (Frontier *et al., 2008).* It is given by the following formula:

$$G = \frac{S-1}{Log\,N}$$

The jaccard similarity index

The Jaccard similarity index is used in statistics to compare similarity between the samples. It is used to study the similarity between species in the range of binary attributes. The Jaccard index between two stations is given by the following formula:

$$Sj = \frac{C}{A+B+C}$$

where 'C' is the number of species common to both surveys; 'A' is the number of species peculiar to the original form and 'B' is the number of species peculiar to the second form.

The Jaccard index is dimensionless and always between 0 and 1. It is constructed so as to be zero if the two readings have no species in common and close to 1 if all species are both surveys identical (Gosselin and Laroussinie, 2004).

RESULTS

The taxonomic composition

A flora is the enumeration of all taxa present in a constitution of the plant community. The woody flora of the Ferlo biosphere reserve is rich with 49 species distributed in 32 genera within 17 botanical families. (Table 1).

From a taxonomic point of view, the most best represented families are:

- Mimosaceae with a frequency of 22.45% of species. This family is rich with 11 species under three different genera's.
- Combretaceae with a frequency of 14.29% with 7 Species in 4 genres.
- Capparidaceae with a frequency of 12.24% having 6 species under four genres.

From the perspective of genera and family, the Combretaceae and Capparidaceae (4 types each) are more diverse than the richest Mimosaceae in terms of species but with less genre. Acacia genus of Mimosaceae constitutes 82% of surveyed individuals.

The surveyed families viz., Mimosaceae, Combretaceae and Capparidaceae contain about 50% of

Table 2. Change in diversity indices in the different zones of the FBR

	Central Zone	Buffer Zone	Transition Zone	RB
Shannon Diversity index (H')	2.92	3.55	3.49	3.45
Equitability index (E)	0.57	0.74	0.68	0.61
Gleason diversity index (G)	3.1	3.53	3.48	4.05
Simpson diversity index (D)	0.79	0.89	0.85	0.85

species recorded throughout the Ferlo biosphere reserve.

The abundance of woody species and families

The graphical representation of the relative distribution of species abundance (Figure 3) showed that similarities beyond floristic lists, presence or absence of species are solely related to the areas of the FBR that have significant differences staffing woods encountered.

In the central area, *Guiera senegalensis* is the most abundant species (40%), followed by *Pterocarpus lucens* (16%), *Boscia senegalensis* (13%) and *Combretum glutinosum* (10%). These four species represent 80% of the total species of the environment. In the buffer zone, *Guiera senegalensis* (21.8), *Pterocarpus lucens*(13.4%), *Boscia senegalensis* (12.8%) and *Combretum glutinosum* (11.4%) are the four most abundant species with a frequency total occurrence of 60%. In the transition area, the order of abundance of species has changed compared to the other two areas. Indeed, *Combretum glutinosum* was fourth with its abundance in the core area and buffer zone, also becomes the most abundant species in the transition zone with a 32.7% frequency of occurrence. It is followed by *Guiera senegalensis* (13.8%), *Boscia senegalensis* (11.8%) and *Pterocarpus lucens* (7.9%).

In the overall area of the reserve forest, the four most abundant species are the same as in the central area with a rank difference. This is *Guiera senegalensis* (29.5%), *Combretum glutinosum* (15.9%), *Pterocarpus lucens* (11.6%) and *B. senegalensis* (10.5%). These four species represent 68% of the total species present in the Ferlo biosphere reserve.

Plenty of families

Throughout the biosphere reserve, the family of Combretaceae is best represented with almost half the number of species (49.7%). It is followed by the family of Caesalpiniaceae (12.7%), Capparidaceae (11.1%) and Mimosaceae (7.3%). This distribution of individuals in the different families is variable from one area to another (Figure 4).

In the central area, Combretaceae (53%), Caesalpiniaceae (17.7%), Capparidaceae (13.3%) and Tiliaceae (7.8%) are the most abundant families. These four families contain more than 90% of the listed individuals. Buffer zone around dominant families varied because although Combretaceae remain the dominant family (39.7%), and the Capparidaceae and Tiliaceae have given way to the family Mimosaceae (16.4%) and of Balanitaceae (13.4%). In the transition area, the Capparidaceae reappears (12%), behind the Combretaceae (49.1%) where the latter is the dominant family at different areas of the biosphere reserve.

The biological types

The woody vegetation in the FBR consists of macrophanerophytes, mesophanerophytes, microphanerophytes and nanophanérophytes (Figure 5). The frequency of different biological types varied from one zone to another. The mésophanérophytes composed of trees whose height ranged from 2 to 8 meters. They are mostly present with over 60% of the identified

Table 3. Similarity matrix (Jaccard Index) between the different zones of the FBR

	Central Zone	Buffer Zone	Transition Zone
Central zone	1	0.47	0.56
Buffer zone	0.47	1	0.58
Transition zone	0.56	0.58	1

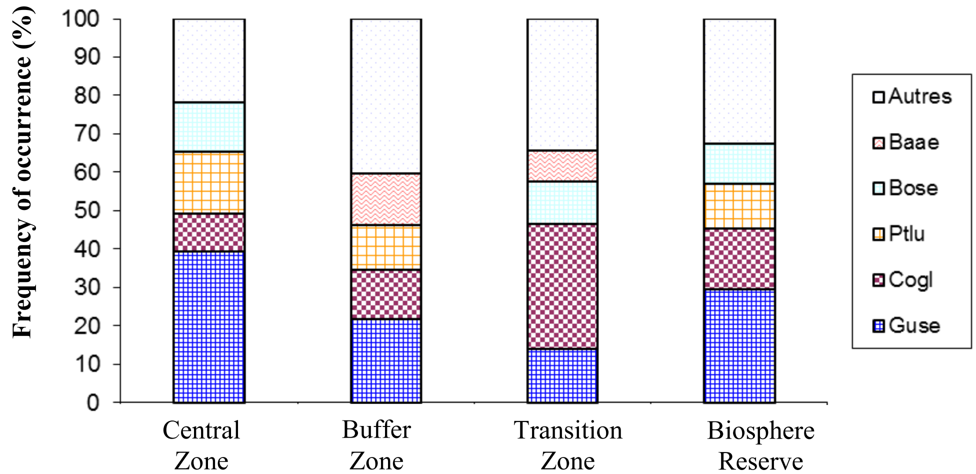

Figure 3. Abundance spectrum of woody species in the FBR

Baae = *Balanites aegyptiaca*, Bose = *Boscia senegalensis*, Ptlu = *Pterocarpus lucens*, Cogl = *Combretum glutinosum*, Guse = *Guiera senegalensis*

species, which is linked to the predominance of bushland in the FBR. The macrophanérophytes which are the second most abundant life forms shows their existance more in the central area (34%) than in the other units of the biosphere reserve. The microphanérophytes are poorly represented in the FBR, but they are more present in the transition area (8%) which is the most anthropized part of the reserve. The nanophanérophytes are very poorly represented.

Phytogeographic affinities

The species found in the FBR mainly belong to the four types of phytogeographic kinds known in West Africa: Sahel, Sahelo-Sudanese, Sudanese and Sudano-Guinean (Figure 6). Generally throughout the FBR, the Sahelian affinity species are the most represented (40%). They are more frequent in the transition area (48%) which is the most anthropized part of the reserve. The Sahelian area is characterized by the plant communities such as to *Guiera senegalensis* and *Boscia senegalensis.* The species with Sudano-Sahelian affinity are more present in the buffer zone at the interface between the conservation area (central area) and zone systems that use multiple land (transition area) that is most anthropized. As for as Sudanese and Sudano-

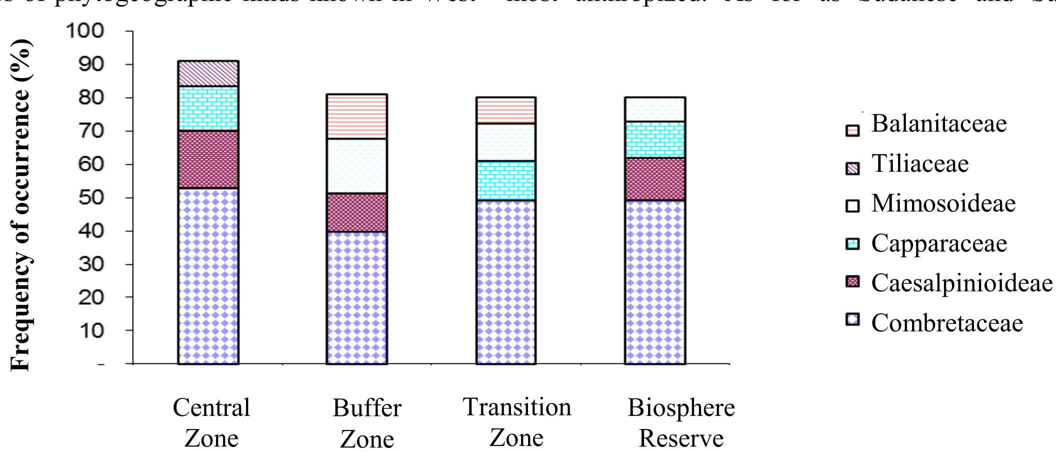

Figure 4. Abundance spectrum of families in the RTBF

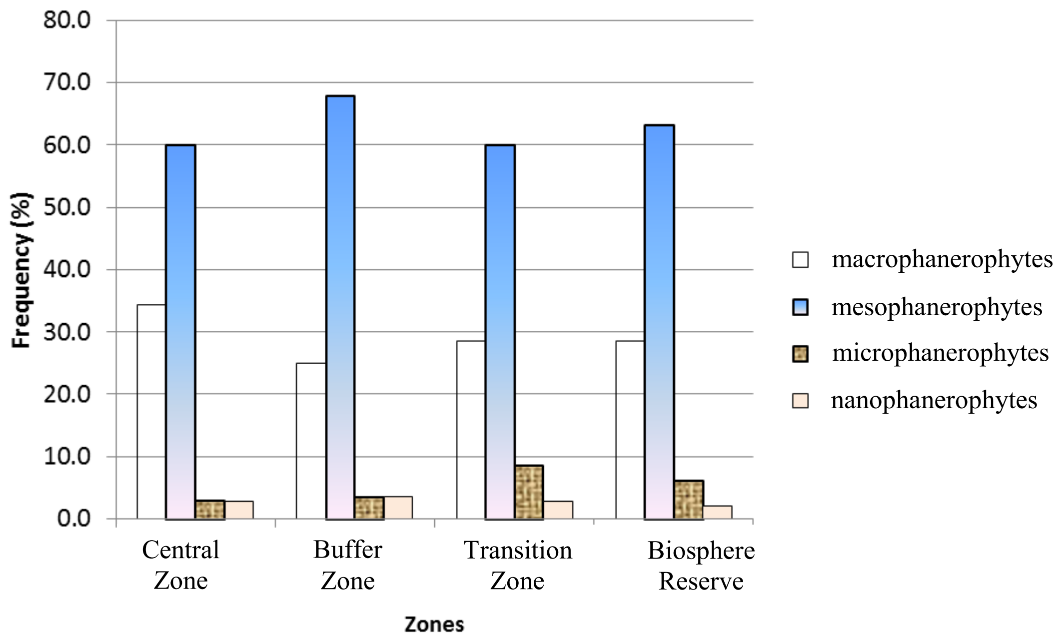

Figure 5. Biological types present in FBR

Guinean affinity, they consist mostly of macrophanérophytes (Adansonia digitata, Anogeissus leiocarpus, Bombax costatum, Lannea acida, Sclerocarya birrea and Sterculia setigera); they are more present in the central area that enjoys legal status of protection as in the other constituent units of the biosphere reserve.

Diversity indices

To understand the evolution of diversity between different areas of the RBF, we have calculated the most used diversity indices in ecology (Table 2). Analysis of the results showed that the Shannon diversity index is quite high in the biosphere reserve with a value of 3.45 bits. It varies little in the different zones with 2.92 in the core zone of 3.55 in the buffer zone and 3.49 in the transition zone.

The other diversity indices calculated including the Gleason diversity index and Simpson index followed the same trend with higher values in the buffer zones, and the transition areas and lower in the central area.

The Fairness index also varies in the same sense, that stand with a higher value in buffer zone (0.74) than in the other areas. The various indices calculated in the different areas of the RB strongly correlate them.

Change in the species composition between zones

Based on vegetation surveys in the presence-absence of species (binary data coded 1-0), the Jaccard similarity indices were calculated and reported in Table 3. This table showed that the floral compositions of different areas of the FBR have average similarities. The matrix showed that according to Jaccard index, the similarity between the buffer zone and the transition area is highest (58%). It is 56% between the core area and the transition area and is lower between the core area and buffer zone (47%).

The two different areas taken into consideration have different floral compositions in more than 40%. In fact it was noted that the existence of many exclusive species are only found in one or other of the three constituent parts of the FBR. This is the case of *Acacia pennata Piliostigma reticulatum, Bombax costatum, Combretum nigricans, Gardenia erubescens, Grewia flavescens, Maerua crassifolia, Mitragyna inermis* and *Ziziphus mauritiana* in the central area, *Entada africana Maerua angolensis, Strychnos spinosa* and *Ziziphus mucronata* in the buffer zone and *Acacia raddiana, Asparagus pauli-gulielmi, Cadaba*

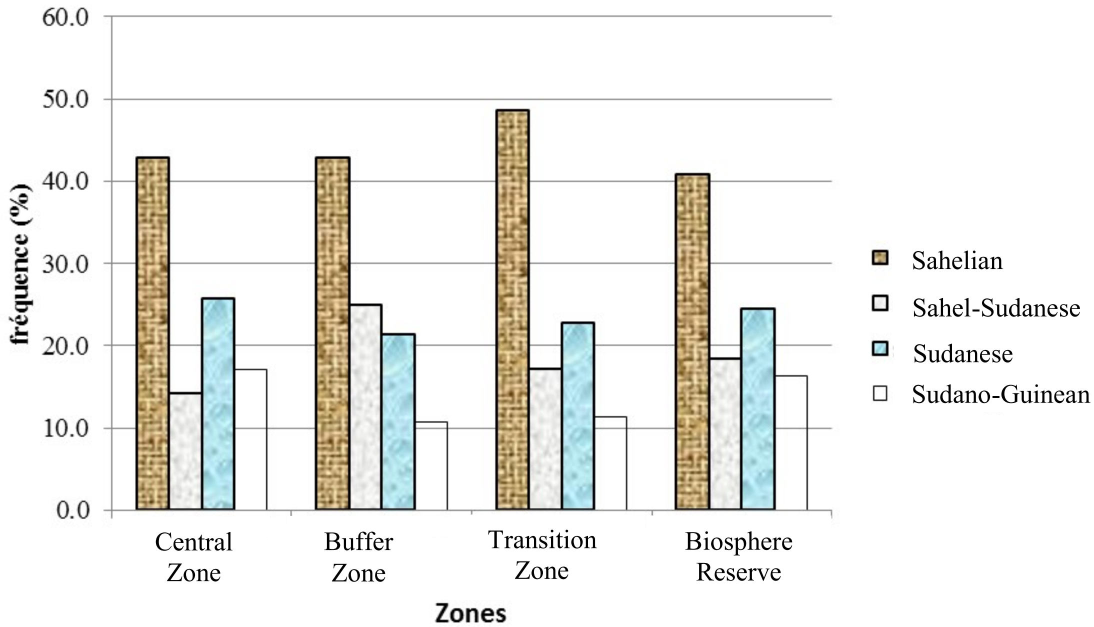

Figure 6. Phytogeographic affinities present in the FBR

farinosa, Combretum aculeatum, Commiphora africana and *Gardenia ternifolia* in the transition zone. Besides these exclusive species, we also reported 11 other species that are present only in two of the three areas of the FBR.

DISCUSSION AND CONCLUSION

The objective of the study is to compare the biodiversity in the three component areas of a biosphere reserve, with a more pronounced anthropisation in the transition zone, the buffer zone and core zone respectively. We also examined the taxonomic richness, biological types, phytogeographical affinity, diversity indices, evenness and composition of the taxa present. Total species richness (S) of the Ferlo biosphere reserve is 49 species distributed in 32 genera within 17 botanical families. However, the value of a specific measure of wealth only makes sense relative to the size of the observed diversity (Gosselin and Laroussinie, 2004) because the number of species continues to increase as the sampling continues (Frontier and Pichod-Viale, 2008). Species richness of an ecosystem is correlated to the area occupied by this ecosystem because greater the surface area greater is the diversity of habitats and therefore more species can settle (Leveque, 2008). Thus, the reliability of species richness depends on the completeness of the inventory. Also, the readings are never exhaustive because of the problem of species detectability (Gosselin and Laroussinie, 2004). Hence, the need for other clues to better understand diversity is inevitable.

Examination of species abundance spectrum showed that the four most abundant species *(Guiera senegalensis, Combretum glutinosum, Pterocarpus lucens* and *Boscia senegalensis)* represent 68% of the total workforce of FBR frequently. Thus, there is a very strong correlation between centésimale frequency and abundance of species. In terms of abundance of families, the family *Combretaceae* is best represented with almost half of the workforce species present (49.7%).

The mésophanérophytes present in Sahelian and Sahelo-Sudanese affinity constitute the biological type mostly in the biosphere reserve. This is explained by the dominance of bushland in Ferlo. The macrophanérophytes which are mostly in Sudanese or Sudano-Guinean affinity are present in the central area, which could be related to the conservation status of the area where human impact is lowest. These biological types, distribution, accurately reflect the ecological conditions of the environment (Mahamane, 2005).

Shannon, Gleason and Simpson diversity indices are quite high in the different areas of the FBR and move in the same direction. These three indices correlate strongly with each other (Nentwig *et al., 2009)* and are higher in buffer zone, transition area and finally in the core area respectively. This reflected a greater diversity in the buffer zone, transition area and in the central area. These high diversity indices also confirm the importance of the ecological potential of the area studied (Gning, 2008). According to Devineau *et al*. (1984), the enrichment of a middle species depends on its availability in the host site and the surrounding flora potential. Equitability also followed the same evolution as diversity indices, which means that the level of organization of timber settlement of the buffer zone would be higher compared to the transition area and the core area.

The analysis of the similarity matrix (Jaccard index) showed that the buffer zone and the transition area are the two closest areas in terms of species composition. This could be explained by the difference in land use patterns in different areas of the biosphere reserve. Indeed, the buffer zone and the transition zone are a home to human settlements and are subjected to multiple uses while the central zone is a conservation area.

Overall, the study of the taxonomic richness, diversity indices and similarity, equitability and taxa composition in the FBR revealed that the buffer zone and the transition area are the subject of multiple uses and suffer human action. They have greater diversity than the central area which is an integral conservation zone.

This fact apparently paradoxical, could be explained by the theory of the average disturbance according to Connell (1978) and Huston (1979) where, an intermediate disturbance level maintains a maximum level of diversity. Indeed, to a degree of intermediate disturbance, there seen a sufficiently to prevent both the colonial and competitor dominance, richness and species coexistence which are maximum (Deconchat and Balent, 2001; Gosselin and Laroussinie, 2004). Long back, it is considered as an accessory phenomenon in the ecological processes; disturbances are now considered an essential element in the functioning of forest ecosystems. It is which ensures the maintenance of biodiversity by acting on the processes of migration and dispersal of species (Spies and Turner, 1999).

Thus, we must transform the way of conceiving human activities, including livestock in the protected areas of Sahel. Unlike the paradigms of the past that accused the farmers, that they are causing land degradation by overgrazing and overloading, but in the recent researches it is showed that pastoral land management practices are not guilty of land degradation (Behnke and Scoones 1992; Niamir, 1996). Grazing stimulates the germination of woody seeds and establishment of seedlings. Herbivores spread the seeds and pods of many species of woody legumes. These plants use herbivores and birds as a primary or secondary vehicle for seed dispersal (Tybirk, 1991). The Sahelian pastoral area is very resilient, capable of rapid regeneration during the rainy season despite being trampled or grazed frequently.

These results prompt us to rethink the best conservation strategy for biodiversity in biosphere reserves that are based on the full protection of the core area. We must transform the way of conceiving human activities in the core areas. Indeed, short-term operating also affect plant diversity.

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