International Journal of Agriculture and Envrinmental Research

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

AGROFORESTRY SYSTEMS AND BIODIVERSITY CONSERVATION IN FITRI, CHAD

Adoum DONA

Department of Life Sciences and Earth, Faculty of Live Sciences, of Earth and Territory planning, University of Sciences and Technology of Ati, Ati, Chad.

DOI: https://doi.org/10.51193/IJAER.2024.10104

Received: 15 Jan. 2024 / Accepted: 06 Feb. 2024 / Published: 21 Feb. 2024

ABSTRACT

The valorisation of land use systems implies the conservation of certain species whose utility depends on the socio-economic and ecological context. The objective of this study was to assess the contribution of land-use systems to biodiversity conservation in the Fitri division of Chad. Semi-structured and repeated surveys were undertaken with a sample of 232 households of which 92 in Amndjamena Bilala, 73 in Abourda and 67 in Alifa. A floristic inventory of woody species was carried out using 50m square plots in the different land use systems. A total of 84 plots were realised with 24 per production system. A total of 1366 woody plants registered, were distributed in 31 species, 30 genera and 12 families. The most representative families are Fabaceae (40.35%). The Shannon index varies from 3.33 bits in the orchards to 3.62 bits in the allotments in the Alifa site. These woody species provide goods and services to the local population. *Acacia ehrenbergiana*, *Faidherbia albida*, *Borassus aethiopum*, *Leptadenia arborea* and *Ziziphus mucronata* have an important value index (IVI) greater than 10%. The Fabaceae family is the most represented with 19 species. The study also revealed that the floristic diversity is important in Alifa locality. The demographic structure of the major species exhibits a normal distribution indicating that young and mature trees are scarce in production systems of Fitri. The future research will be focused on productivity of the agroforestry systems.

Keywords: Agroforestry systems, Biodiversity, Conservation, Multipurpose tree species, Fitri Division, Chad.

1. INTRODUCTION

In rural areas, local people have indigenous knowledge of biodiversity management. In the Fitri division, biodiversity plays many roles in improving people's living conditions [1,2]. Biological diversity provides human nutrition in terms of both quantity and quality. Commercialized forest

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

products are a source of household income [3]. In most provinces, biodiversity is the source of animal breeding productivity in Chad, where extensive livestock farming is well developed. It guarantees the supply of fuel, timber and various pharmaceutical products [4]. In agroforestry systems, conserved woody biodiversity is an important factor in agricultural production. It protects soils from water and wind erosion and enriches them with organic matter from the decomposition of litter accumulated in the undergrowth [1]. Despite its ecological and socio-economic importance, biodiversity is threatened with degradation by a number of factors, including climate variability, declining soil fertility and demographic pressure [5]. Combine effets of climate change and anthropic pressure contributes to the disruption of the natural balance and compromises the wood's potential [6,7]. Agroforestry is a land use system where woody species are deliberatelly associated with cultures [8]. It can resolve certains environmental problems in country like Chad where degradation of natural ecosystems is a key challenge [1]. Agroforestry systems play an important role in the sequestration of carbone. They equally permit various food produits they provide to ensure food security and improve the living conditions of farmers [9, 10,11]. In Chad, Fitri division belongs to ecosystems rich in natural ressources. In spite of this richness, scientific knowledges are scarce on biological diversity of the area except those reported on climate change [12]. The main purpose of the present work is to fill the gap by assessing the influence of land use systems on biodiversity conservation in Fitri, Chad. More specifically, characterize, evaluate the diversity and the structure of the ligneous population of the land use systems of Fitri.

2. MATERIALS AND METHODS

2.1. Study site

The division of Fitri is situated in the south west of the province of Batha, in the centre of Chad between 12 and 13th parallel north and 17 and 18 th meridian East. Am N'djamena Bilala, Alifa and Abourda are the sites explorated. Fitri division belongs to sahelian bioclimatic zone between the isoyets 200 and 800 mm. The thermic scheme is marked by a long dry season of 9 months that the most hot one is April (40 - 43°C) and the relative cold period ranges from December to Febuary (11 - 23°C) [13].

The topography is little damaged and covered by endoreique rivers which duration depend on the variability of the pluviometry and their position in the province. Soils are constituted of fomations with dominance of sand and clay –muddy. The vegetation is of the Saharan type, with scattered and often dense thorny shrubs. The herbaceous stratum is composed of species like *Dactyloctenium aegyptium*, *Schoenefeldia gracilis*, *Eragrostis tremula* et *Aristida* sp. Woody vegetation is represented by arborescent populations, including species such as *Balanites aegyptiaca*, *Acacia tortilis*, *Leptadenia pyrotechnica*, *Acacia nilotica*, *Maerua crassifolia*, *Boscia*

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

senegalensis. Plains liable to flooding and zone of low pressure keep often palm grove of *Borassus aethiopum* and *Hyphaene thebaica.* They notice equally the presence of others species such as *Bauhinia rufescens*, *Acacia senegal*, *Acacia seyal*, *Faidherbia albida*, *Ziziphus mauritiana*, *Prosopis juliflora* and *Tamarindus indica*. Agriculture, breeding and fishing are the main activities of the population. Agroforestry systems are intensively associated to the production of *Sorghum durra*, *Zea mays*, *Vigna unguiculata*, *Arachis hypogaea and Ipomoea batatas*. Truck farming products are constituted by foodstuffs like *Abelmeschus esculentus*, *Lycopersicum esculentum*, *Citrullus vulgaris*, *Cucumis sativus*, *Capsicum frutescens* [14]. These speculations are main food ressources and income of households in Fitri Division.

2.2. Methodological approach

2.2.1. Household interviews

Household surveys were carried out in semi-structural interviews with a questionnaire already elaborated and administrated per group of 10 persons or individually. Questions were directed on 3 axis : (i) inventory of different species conserved in agroforestry systems ; (ii) type of land use systems ; (iii) use of each species. The choice of farmers was at random while the group members were constituted by heads of exploitation. The population survey included a sample of approximately 2% [15]. A total sample of 232 households distributed in 92 in the locality of Am N'djamena Bilala, 73 in Abourda and 67 in Alifa. To contribute to the household interviews, respondents must be farmers in the area for about 30 years. The main difficulty encountered was the translation of questions in local languages.

2.2.2. Floristic inventory

Agricultural production systems of Fitri division are characterized by various agrosystems of which the main are homegardens, bushfarms, orchards of *Mangifera indica*. These systems are made up of many domesticated fruit trees, but spontaneous species were also retained in these production systems. A systematic inventory of woody plants was carried out using sub-plots of 50 m x 50 m (2500 m^2) in different agrosystems abovementionned. This technics was inspired from the methodology used on the evaluation of plant diversity and quantification of ecosystemic services in Ferlo in senegal [5]. In total 84 floristic records were made either 24 per production system. Various materials were used : a double decameter and a tape were used to measure the plots and the diameter at chest height. The global positing system was used to register geographical coordinates while cuttlas was to free the passage and delimitate plots. Scientific names of species were determined on the basis of the illustrated new flora of Chad [16].

2.2.3. Data analysis

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

Quantitative data were subjected to analysis of variance and significant means were separated by Duncan Multiple Range Test. Statgraphics plus 5.0.was the programme exploited. The logiciel R was used to determine diversity indices. In addition, the index of importance of species was calculated in percentage from formula developped [17]. All species which the importance value is more or equall to 10% is considered as ecologicaly important [18, 19].

$$IVI = 100 * \left[\left(\frac{n_i}{N}\right) + \left(\frac{g_i}{G}\right) + \left(\frac{f_i}{F}\right) \right]$$

with $\frac{n_i}{N} x100$, the relative density of the species i ; $\frac{g_i}{G}$, the basal area of the species i ; $\frac{f_i}{F} x100$, relative frequency of the species i.

In the same way, the importance index of the family was calculated through the sommation of the relative density, relative dominance and relative diversity.

$$FIV = 100 * \left[\frac{Ni}{\sum N_i} + \frac{G_i}{\sum G_i} + \frac{D_r}{100} \right]$$

Family which the importance value is greater or equall to 10 % is considered ecological important [20].

The specific diversity is determinated by the cacul of indices of diversity :

- Shannon-Weiner (H') index in bits :

$$(H') = -\sum_{i=1}^{s} P_i \log_2 P_i$$

$P_i = \frac{n_i}{N} x100$, is the relative abundance of each species i.

H'is minimal (H' = 0), if all the individuals of population belong to one and the same species ; H' is maximal when all the individuals are distributed in the equally way [21]. This index is used to calculate the species diversity, comparatively to the maximal diversity which is the logarithm in base 2 of species number (S) :

$$H_{\max} = \log_2(S)$$

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

The index of Shannon is often going with the Equitability of Pielou or R [22], called equally equirepartition index or again regularity which represents ratio of H'/ H_{max} in the population :

$$R = \frac{H'}{H_{max}}$$

It the realisation degri of the maximal diversity [23].

The Simpson Diversity Index (D') is the probability for that two individuals chosen at random either different. The maximum of diversity is represented by the value 1 and the minimum of diversity by the value 0.

$$(D') = 1 - \sum (n_i / N)^2$$

ni = number of individuals for the species i ; N = Total effective of individuals of all the species.

3. RESULTS

3.1. Floristic characteristics of land use systems

A total of 1366 plants were recorded in the Fitri division. They are distributed in 31 species, 30 genera and 12 families (Table 1). Of the 12 families, the Fabaceae is globally, the most diversified with 14 genera, 19 species and 533 plants of the woody flora.

Table 1: Taxonomic distribution of floristic richness

Families	Individuals		Genera		Species	
	Number	Abundance (%)	Number	Abundance (%)	Number	Abundance (%)
Fabaceae	533	40.35	14	46. 67	19	52.77
Anacardiaceae	183	13.85	2	6.67	2	5.56
Arecaceae	92	6.96	2	6.67	2	5.56
Capparaceae	88	6.66	2	6.67	2	5.56
Zygophyllaceae	73	5.53	2	6.67	3	8.33
Rhamnaceae	71	5.37	2	6.67	2	5.56
Myrtaceae	69	5.22	1	3.33	1	2.78
Meliaceae	68	5.15	1	3.33	2	5.56
Moringaceae	51	3.86	1	3.33	1	2.78
Asclepiadaceae	51	3.86	2	6.67	1	2.78
Rutaceae	42	3.18	1	3.33	1	2.78
Total	**1321**	**100.00**	**30**	**100.00**	**36**	**100.00**

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

Others families are less represented with 01 to 03 species. In terms of specific richness, 02 families dominate the flora of the study area. It is respectivelly Fabaceae (40.35%), and Anacardiaceae (13.85%).

3.2. Ecological importance of land use systems

Different tree species found in the land use systems of Fitri division play important ecological roles. The analysis of the index value importance of species shows some useful plants with great ecological importance value (IVI ≥ 10). Independently to the ecological zone, they are *Mangifera indica*, *Psidium guajava*, *Tamarindus indica*, *Moringa oleifera*, *Acacia ehrenbergiana*, *Faidherbia albida*, *Borassus aethiopum*, *Leptadenia arborea* and *Ziziphus mucronata* (Table 2). The Ecological importance Index of species ranges from 10.22 in *Acacia ehrengiana* to 14.73 % in *Mangifera indica*. Thus *M.indica* holds the highest one. It is a multipurpose tree species valued by local population. Fruits of the species are consumed and commercialized by households in regional markets.

Table 2: Index of ecological importance of species

Espèce	Relative density (%)	Relative Frequency (%)	Relative dominancy (%)	IVI (%)
Mangifera indica	3.10	5.80	5.83	14.73
Psidium guajava	3.97	5.49	3.78	13.24
Tamarindus indica	2.85	3.58	5.53	11.96
Moringa oleifera	2.66	4.97	2.93	10.56
Acacia ehrenbergiana	2.22	4.47	3.53	10.22
Faidherbia albida	1.52	4.83	4.49	10.84
Borassus oethiopum	2.87	2.74	4.68	10.29
Leptadenia arborea	2.65	4.97	2.85	10.47
Ziziphus mucronata	1.52	4.38	4.47	10.37

IVI= Index Value Importance

These species play great functions in producing goods and ecosystemic services. The present findings corroborate those reported in Benin natural forests where important ecological species index are the most prized [24,25]. In Mali, woody formations with high important index beneficit a status of protection from local population [26]. The more the important index of species is high, the more the global density of species is also high [27]. The important index is linked to the strong density of trees which will provoke competition for the light. The high value of ecological important index in a medium is attributable to favourable climate conditions to regeneration of

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

ligneous species. Species of high importance value are essential for the fighting against food insecurity and production of socio-ecological services which need to be perpetuate.

Many families among which Fabaceae, present high ecological Importance value more or equal to 10 (FIV≥10) (Fig.1).

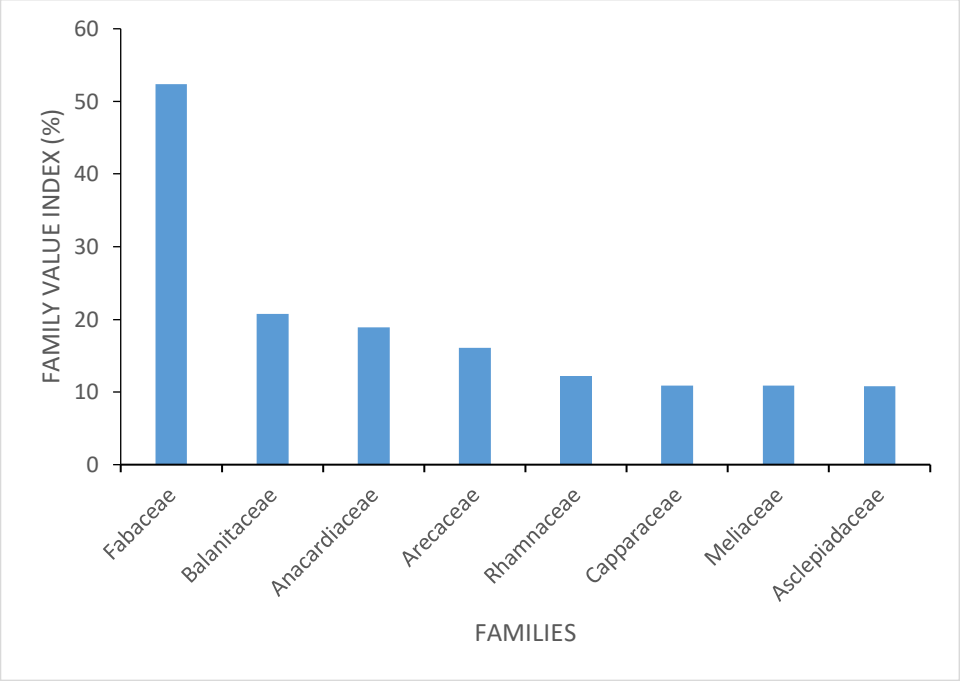

Figure 1: Index of importance value of Families

The most important families according to family importance value is the Fabaceae which performed with 19 species. It is followed by the Arecaceae, Anacardiaceae and Rhamnaceae families with 2 species. There is a significant difference among the families in terms of Ecological Importance Value (0.000 < 0.001). The most diversified families are also the most dominant. This dominance can be explained by their relative density, and they also benefit from the protection of the local population. They play an important role in the satisfaction of the vital needs of farmers which justify their protection and conservation in agrarian landscapes. Fabaceae are used in agriculture as fertilizer [28]. Anacardiaceae species are of socio-economic importance to farmers. *Mangifera indica* fruits are rich in carbohydrates, water and various vitamins. The leaves and bark are used to treat diabetis by regulating the vascularisation of the pancreas [29, 30]. Species from the families of Arecaceae and Rhamnaceae produce edible fruits [31]. *Moringa oleifera* is a Zygophyllaceae whose young fruits, flowers and leaves are consumed as a vegetable reputed to be rich in protein and vitamins. These observations are in line with

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

those reported in Niger [32,33]. The authors reported that the regenerative capacity of the species remains a characteristic of their adaptation to edapho-climatic conditions.

3.3. Floristic diversity analysis of land use systems

The specific diversity analysis permits to appreciate biodiversity distribution in differents production systems such as home gardens, *Mangifera indica* orchards and bushfields (Table 3).

Table 3: Diversity of Fitri agrosystems

Localities	Agrosystems	Richness	Abundance	H’	D’	R
Am N’Djamena Bilala	Homegardens	503	36.82	3.60	0.95	0.89
	Bushfarms	427	31.26	3.46	0.93	0.77
	Orchards	436	31.92	3.44	0.94	0.78
Alifa	Homegardens	519	37.31	3.62	0.97	0.82
	Bushfarms	483	34.72	3.55	0.95	0.80
	Orchards	389	27.96	3.33	0.91	0.79
Abourda	Homegardens	602	37.27	3.61	0.96	0.83
	Bushfarms	521	32.26	3.47	0.94	0.82
	Orchards	492	30.46	3.41	0.92	0.80

H’ = Shannon Index ; D’ = Simpson Index ; R = Equitability of Pielou

The high specific richness was registered in the production systems of Abourda (1615 individuals). The people of this region have a good knowledge of biodiversity conservation. The Shannon index varies from 3.33 bits in the orchards to 3.62 bits in the allotments in the Alifa site. Simpson's index is also high in the Alifa area, at 1(0.97), indicating equi-partition. The Pielou equitability index is low in the Am N'Djamena Bilala site. It shows the imbalance and poor distribution of biological diversity. This situation is due to the over-exploitation of biodiversity. In general, whatever the zone considered, the Shannon index and Pielou equitability present the same trend. Similar studies have been carried out in tropical agroforests, showing a wealth of trees and shrubs, whose floristic composition varies according to farmers' needs [34,35]. However, these findings are less than those obtained in *Diospyros mespiliformis* agroforestry parklands of the Centre Niger [36].

3.4. Useful tree species

Farmers of the Fitri manage both local and exotic multipurpose tree species in their production systems. The phytodiversity of the area regroups many species of great socio-economic and ecological importance which are appreciated by farmers of the Fitri. The most important local species protected in the production systems are *Acacia ehrenbergiana, Borassus aethiopum*,

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

Faidherbia albida, *Leptadenia arborea*, *Tamarindus indica* and *Ziziphus mucronata*. *F. albida* plays an important role in soil fertility, animal nutrition and traditional medecine. It is a providential tree of the sahel according to the farmer perception. The quasi totality of the farmers claims that *B.aethiopum* is a tree species used for all needs. The pulp of the fruits is eaten or used to prepare beverage while the hypocotyl from seedlings are cooked and eaten as vegetables. The leaves are used for the roof of traditional house, hats, traditional braid, etc. while the wood is sawn into planks used in house construction and for handicraft. These hypocotyls are appreciated and commercialized in local and regional markets. The fruits of *Tamarindus indica* and *Ziziphus mauritiana* are consumed and the spine from the stem of the Rhamnaceae is used in handicraft. These species are multipurpose species of greatest importance in the sahel and exhibit similar demographic structures in Fitri production systems.

3.4.1. Diametric structure of useful tree species

The demographic structure of *Moringa oleifera*, *Psidium guajava* following the diameter has shown a normal distribution with the optimum at 40.1-60 cm (Fig.2). *Balanites aegyptiaca* and *Mangifera indica* show their's at the class of the diameter 60.1-80 cm. This analysis presents a wide representation of young individuals in all the populations. This structure has a belt allure indicating that the population has a normal stable distribution. These structures are relatively well represented, with only a small number of adult individuals with a diameter greater than 70.1-80 cm. This is because these species are of vital importance to rural populations. Leaves of *Moringa oleifera* are consumed like vegetable and theirs seeds are used against divers pathologies notably diabetis and hypertension [37]. The induction of the vegetative multiplication can perpetuate the species, in particular in sahelian medium where the water stress is pronounced, the agropastoral and anthropique disturbing are high [38].

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

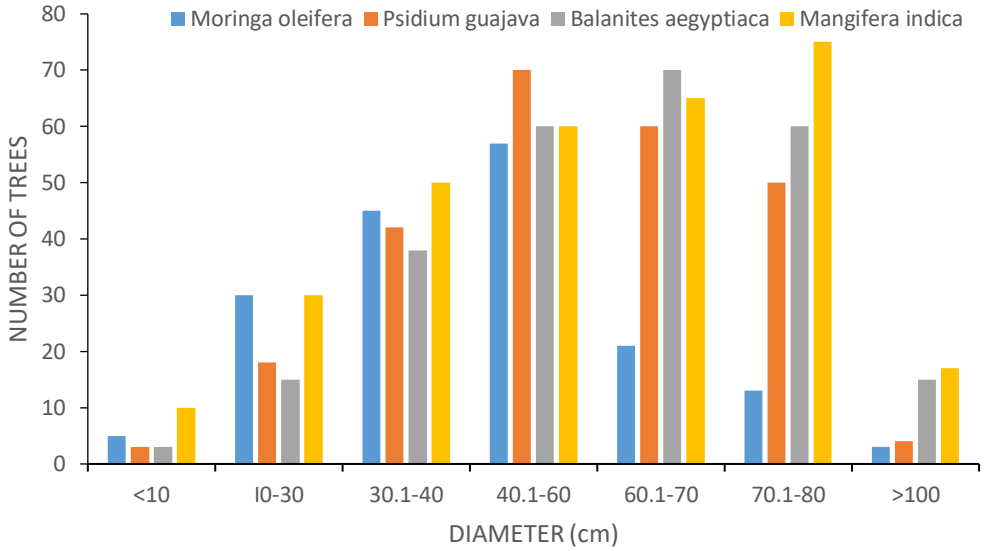

Figure 2: Diametric stucture of major species

Psidium guajava fruit are consumed and commercialized in all the region. Its leaves are used to treat dysanthery in children. Fruits of *Balanites aegyptiaca* are both used. The pulp is rich in glucide and the seed contains lipid. Its fruits play an important role in food quality. The structure of *Mangifera indica* presents a J distribution with young and adult individuals more or less stable. *M. indica* is a conventional fruit tree species with socio-economic interest. Its fruits are rich in glucide and divers vitamins. *M. indica* is one of the most widely consumed and sold foodstuffs in the region and abroad.

4. DISCUSSION

Farmers of Fitri have good knowledges on their environment and valorized local phytodiversity for food, medecine, etc. [12]. The good management of the biodiversity in agroforestry systems supplies essential ecosystem services to population through informal economies. Analogous findings were reported in Cameroon [39,40]. In the tropics, preservation of useful trees species in agrosystems remains a rule during clearing, hence the actual physionomy of the agroforestry systems. Conservation and management of useful tree species in farms explains the actual floristic composition of agrosystems. In the same time, the proportion of tree species retained in the farms increases compared to the natural vegetation. *F.albida* is one of the multipurpose tree species well known in the sahel as providential tree. Ecologically and contrary to others tree species, it presents a reverse phenology. Homegardens, busfarms and ochards figure among the most representative land use systems of Fitri division of Chad. These agrosystems contribute

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

effectively to the conservation of biodiversity, the improvement of the living conditions of the populations.

4.1. Floristic characteristics of land use systems

A total of 1366 plant stems distributed in 31 species, 30 genera and 12 families were recorded in the agrosystems of Fitri. Different types of species are met in sahelian parklands: exotics and locals. The low floristic richness observed in the parklands is thought to be due to the use of the species by human populations to satisfy their daily needs, as well as to the ecology of the crops produced. The conservation of phytodiversity by local populations in their agrosystems can be explained, on the basis of food preference on the one hand and endogenous knowledge of the usefulness of species deliberately conserved in production systems on the other. These results are in accord with those reported by many researchers in Niger [41, 42, 43]. Meanwhile, 31 species, 30 genera and 12 families were equally reccorded in Centre of Niger while 37 others were in agroforestry parklands of Dan Saga of Niger [42,43]. These results are higher than those obtained in the Sahel parklands with 16 species in *Neocarya macrophylla* agroforestry parklands and 13 in those of *Balanites aegyptiaca* in West Niger [33, 44]. However, this specific richness is less than that reported in the sudanian zone of Niger where 55 woody species found were distributed into 32 genera and 23 families [45]. Nevertheless, the findings reported in the present study are similar to those reported in Burkina Faso [46]. According to this author, the flora of an area is said to be rich when it referms 31 to 40 species, independently of the vegetation type. The abundant families are those of Fabaceae and Anacardiaceae. These families are constituted by woody species used by the farmers of the Fitri division (*Acacia senegal*, *Faidherbia albida*, *Mangifera indica, etc*...) for their multipurpose uses. Focus was on 3 main functions fill by woody species conserved in land use systems among which soil fertility, pharmacopea and household sources of income were highlighted [47]. These investigations permitted to put into evidence families of Fabaceae, Anacardiaceae, Arecaceae and Capparaceae. This importance could be due to their adataption, their dissemination modes and their uses. Fabaceae are generally fodder plants with zoochorous seeds disseminated by animals whereas Anacardiaceae and Arecaceae are characterised by their edible fruits consummed by human being and animals who facilitated their dissemination [48]. Capparaceae have anemochorous seeds disseminated by wind [33]. The utility of these families in sahelian zones remains on the fact that they contains species which are resistant and adapted to lack of rain as well as to high temperatures [49]. The most important ecological plant species are *Mangifera indica*, *Psidium guajava*, *Tamarindus indica*, *Moringa oleifera*, *Acacia ehrenbergiana*, *Faidherbia albida*, *Borassus aethiopum*, *Leptadenia arborea* and *Ziziphus mucronata*. The major ecological families are dominated by Fabaceae, Anacardiaceae, Arecaceae, Rhamnaceae, Moringaceae and Asclepiadaceae. The

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

majority of species conserved in farms derived from these families because they play important roles in the population life.

4.2. Diversity in land use systems

Farmers in these regions have a good knowledge of biodiversity management. They are aware of the importance of *in situ* conservation. Biodiversity indices are evolving in the same direction. The low values observed in orchards can be explained by selective weeding and precarious climatic conditions. Between production systems, the indices move in the same direction. These results are similar to those obtained in the Tamour (3.24 bits) and Simir (3.28 bits) agroforestry parklands in western Niger [44]. These results can also be compared with those recorded at Guidan Roumdji in *Guiera senegalensis* - *Piliostigma reticulatum* parklands in south-central Niger [41]. In general, whatever the area considered, the Shannon index and Pielou equitability move in the same trend. Similar studies conducted in tropical agroforests and have shown a high richness of trees and shrubs and a floristic composition that varies according to farmers' needs [34,35]. However, these results are inferior to those obtained in *Diospyros mespiliformis* agroforestry parklands in Central Niger [36].

4.3. Diameter structure of tree species

The demographics of Futri's production systems show a normal diameter distribution, regardless of the type of agrosystem. The diameter distribution of species in Sahelian agrosystems is roughly belt-shaped. The maximum number of individuals is observed in the 30.1-40 cm interval, independently of the species selected. This suggests that in these agrosystems, regeneration of young seedlings and management of old trees are difficult. In general, these main species have a homogeneous diametral structure. The belt shape shown is similar to those reported in parklands in Niger [49]. Ecologically, *M.indica* production systems provide many ecosystem services [50]. *M. indica* planting and domestication practices are being widely disseminated in the Fitri division. These results are comparable to those which reported that socio-economic species contribute to poverty reduction [51]. The same finding was made in the Sudanian zone of Benin [52]. These results corroborate those reported by some authors in Cameroon [37, 53] and Ivory Coast [54, 55].

The Fitri division agroforestry systems are of great importance in the fight against climate change and in maintaining phytodiversity. However, knowledges on their carbon sequestration potential are still very limited [56]. In the REDD+ perspective, the ecosystem services provided by carbon markets on the international level, agroforestry systems deserve special attention. More attention needs to be taken in relation to ecological conditions of Fitri.

ISSN: 2455-6939

Volume: 10, Issue: 01 "January-February 2024"

5. CONCLUSION

The study of the Fitri agroforestry systems showed the existence of a good potential for woody biodiversity. A total of 1366 individuals were recorded and distributed into 31 species, 30 genera and 12 families. The most diversified family is Fabaceae, with 19 species reprenting 40.35% of the woody population of the division. This family is the cornerstone of the floristic structure of the region. The most important ecological species are : *Mangifera indica*, *Psidium guajava* and *Tamarindus indica*. These species have the advantage of being planted and preserved by local farmers in their fields. The locality of the area with the highest biodiversity is Abourda (1615 individuals). The demographic structure of the major species exhibits a normal distribution indicating that young and mature trees meet difficulties to grow in production systems of Fitri. The significant biological diversity of the area demonstrates the endogenous knowledges of Fitri farmers on biodiversity management and valorization. The next step will be focused on carbon sequestration potential of the agroforestry systems of Fitri.

ACKNOWLEDGEMENTS

The authors extend their thanks and gratefulness to the administrative and traditionnal authorities of the sahelian zone of Chad who facilitated the accessibity to the households and agrosystems. A sincere thank is extended to the inhabitants of Fitri for their hospitality and their involment in the conduct of this work. A special gratitude is sent to anonymous reviewers for their constructive critics and pertinent comments which permit to improve the quality of the paper.

REFERENCES

[1] Dona A., Mapongmetsem P.M., Dongock N.D., Pamboudem N.A., Fawa.G and Aoudou D.S., 2016. Phytodievrsity and carbon stock in Sudanian savannahs zone of Tandjile-East of Chad, *International Journal of Applied Research* 2(9): 455-460.

[2] Raimond C., Zakinet D., Mugele R., Kemsol N A., Mbagogo A., Yali-kunT., Brahim B.A., Madjigoto R., Schuster M., Sylvestre F., Deschamps P., 2017. Les nouveaux enjeux pour le lac Fitri, entre variabilité environnementale, croissance démographique et conflit d'usage. In : *livre des résumés étendus du colloque International Recherche croisée sur les écosystèmes lacustres tchadiens, Ndjamena*, Tchad, 25-27 avril 2017, 601p.

[3] Mapongmetsem P.M., Dona A., 2010. Land use systems and biodiversity conservation in east Tandjile, Chad. *Scripta Bot. Belg*, 46 : 285.

[4] Béchir A.B., Mopaté.L.Y., 2015. Analyse de la dynamique des pâturages autour des ouvrages hydrauliques des zones pastorales du Batha ouest au Tchad, *Afrique Science*, 11(1) : 212-226.

[5] Ngom D., 2013. Diversité végétale et quantification des services écosystémiques de biosphère du Ferlo (Nord-Sénégal). Thèse, ED-SEV/UCAD, Dakar, 167p.

[6] Mbolo M.C. & Tamandjong V., 2016. The role of cocoa agroforestry in conserving forest tree diversity in Central Region of Cameroun. *Agroforestry systems* 90(4): 577-590.

[7] Zapfack L., Chimi D.C., Noiha N.V., Zekeng J.C., Meyam-ya D.G & Tabue M.R.B., 2016. Correlation between associated trees, cocoa trees and carbon stocks potential in cocoa agroforests of Southern Cameroun. *Sustainability in Environment* 1(2): 71-84.

[8] Nair P.K.R. & Garrity D., 2012. Agroforestry; the future of global land use, advance in agroforestry *springer. Dordrecht*, 541p.

[9] Torquebiau E., Mary F & Sibelet N., 2002. Les associations agroforestières et leurs multiples enjeux. *Bois et forêts des Tropiques*, 271 : 23-34.

[10] Jagoret P., Michel-Dounias L & Malézieux E., 2011. Long-tern dynamics of cacoa agroforets: a case study in Central Cameroon. *Agroforestry systems*, 81 : 267-278.

[11] Mapongmetsem P.M., Nduryang J.B.N., Fawa G., Dona A., 2015. Contribution à la connaissance des produits forestiers non ligneux de la zone soudano-sahélienne du Cameroun. Kapseu C., Nzié W., Nso E., Silechi J., Ngomo H., (*Eds*). Biodiversité et changements globaux : valorisation des effluents des industries, des résidus agro-pastoraux et forestiers. *Actes du Colloque International* du 21 au 23 juillet 2015 à Ngaoundéré, pp.139-147.

[12] Dona A., Lamy Lamy G. M., Anguessin B., Fawa G., Mapongmetsem P. M., 2023. Agricultural Production Systems and Climate Change Ductility Enhancement in the Fitri Watershed in Chad. *American Journal of Agriculture and Forestry*. 11 (4) : 119-127. Doi: 10.11648/j.ajaf.20231104.11

[13] Garba I., Touré I., Ickowicz A., 2012. « Evolution historique de la pluviosité ». In système d'information sur le pastoralisme au Sahel. Atlas des évolutions des systèmes pastoraux au Sahel 1970-2012. *Fao et Cirad*, (éd.) : 8-11.

[14] GTZ, 2008 : coopération technique allemande. Programme « mise en œuvre de la convention sur la biodiversité » communication environnementale. Vulgariser la Biodiversité. Eschborn, Allemagne 2p.

[15] IRD, 2012. Population, développement et dividende démographique au Tchad. Replacer la population du centre des trajectoires de développement, 18p.

[16] Jean-César., Cyrille Ch., 2018. Flore Illustrée du Tchad, 767 p.

[17] Yédomonhan H., Hounadagba C.J., Akoéginou A., Vander Maesen L.J.G., 2008. Structure et diversité floristique de la vegetation des inselbergs du secteur méridional du centre-Bénin. *Syst. Geogr.* 78 : 111- 125.

[18] Felfili J.M., Silva Junior M.C., Sevilha A.C., Fagg C.W., Walter B.M.T., Nogueira P.E & Rezende A.G., 2004. Diversity floristics and structural patterns of cerrado vegetation in Central Brazil, *Plant Ecology*, 175 : 37 – 48.

[19] Neelo J., Teketay D., Kashe K., Masamba W., 2015. Stand structure, diversity and regeneration statut of woody species in open and exclosed. Dry woodland sites around Malapo farming areas of the Okavango Delta, Northeastern Bostwana. *Open Journal of Forestry*, (5) : 313 – 328.

[20] Gonmadje C. F., Doumenge C., Sunderland T. C. H., Balinga M. P. B., Sonké B., 2012. Analyse phytogéographique des forêts d'Afrique Centrale: le cas du massif de Ngovayang (Cameroun). *Plant Ecology and Evolution*, 145 (2): 152-164.

[21] Dagnelie P., 2006. Statistique théorique et appliquée. Gembloux, Belgique, *De Boeck*, 451p.

[22] Faraway J.J., 2004. Linear models with R. Chapman and hall/CRC, 240p.

[23] Scherrer B., 2007. Biostatistique. Volume 1, 2eme*édition, Guëtan Morin (éditeur)*, Montréal, 816p.

[24] Akoégninou A., 2004. Recherches botaniques et écologiques sur les forêts naturelles du Bénin (Afrique de l'Ouest). Thèse d'État Université de Cocody-Abidjan, 314p

[25] Adjakpa B.J., 2006. Flore et végétation actuelle du Bas delta de l'Ouémé des zones humides du sud-Bénin. Thèse de Doctorat 3eme cycle en Biologie végétale, option Écologie. Faculté des Sciences et Techniques/UCAD, Dakar (Sénégal), 88p.

[26] Birnbaum P., 2017. Spatialisation de la diversité et de la structure : un enjeu pour la conservation des forêts tropicales. Biodiversité et Ecologie. Université de Montpellier, France, 79p.

[27] Comita L.S., Condit R & Hubbel S.P., 2007. Developmental changes in habitat associations of tropical trees. *Journal of Ecology*, 95 : 482-492.

[28] Douma S., Idrissa S., Morou B., Mamoudou H., Saley K., Mahamane A., Saadou M., 2012. Diversité des peuplements ligneux des parcs agroforestiers de la Reserve Totale de Faune de Tamou (Niger). *Etudes et recherche Sahélienne, Sciences Agronomiques*, 18 : 55-62.

[29] Fandohan B., Assogbadjo A. E., Glélé Kakai R & Sinsin B., 2011. Géographical distribution, tree density and fruit production of *Tamarindus indica* L. (Fabaceae) across three ecological regions in Benin. *Fruits*, 66 (1) : 53 -62.

[30] Vinceti B., Ickowitz A., Powell B., Kehlenbeck K., Termote C., Cogill B & Hunter D., 2013. La contribution des forêts aux régimes alimentaires durables. Document d'Information pour la Conférence Internationale sur les forêts par la sécurité alimentaire et la nutrition. *Document FGR/9F*, FAO, Rome, Italie 13p.

[31] Tchobsala A., Amougou P & Mbolo M., 2010. Impact of wood cut on the structure and Floristic diversity of vegetation in the peri-urban zone of Ngaoundéré (Cameroon), *Journal of Ecology and the Natural Environment*, 2 (11) : 235 – 258.

[32] Sani A.R., 2009. Caractérisation biophysique des ressources ligneuses dans un site reverdi et un site dégradé dans le Département de MIRRIAH, Mémoire de fin de cycle de l'obtention du Diplôme d'Ingénieur d'Eaux et Forêts, Université Abdou Moumouni, 62 p.

[33] Dan Guimbo I., Mahamane A., Ambouta J.K.M., 2010. Peuplement des parcs à Neocarya macrophylla (Sabine) et à Vitellaria paradoxa (Gaertn cf) dans le Sud-Ouest Nigérien : diversité, structure et régénération. Int. *J.Biol.Chem.Sci*, 4(5) : 1706-1720.

[34] Michon G., Mary F., Bompard J., 1986. Multistorey agroforestry garden systems, 5:315-338.

[35] Mapongmetsem P.M., Etchiké D., Ngassoum M.B., 2016. Conservation et valorisation de la biodiversité dans les agroforêts de la zone périurbaine de la ville de Bafia (Région du Centre au Cameroun). *Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo*, 6 : 60-69.

[36] Ali A., Morou B., Inoussa M.M., Abdourahamane S., Mahamane A et Saadou M., 2017. Afrique Science, 13(2) : 87-100, *http://afriquescience.info*

[37] Saj S., Durot C., Mvondo-Sakouma K., Tayo Gamo K & Avana-Tientcheu M.L., 2017. Contribution of companion trees to long-term tree conservation carbon storage and agroforest sustainability a functional analysis of the diversity in cacao plantations of Central Cameroon. International *Journal of Agricultural Sustainability* 15: 282-302.

[38] Zegeye H., Teketay D & Kelbessa E., 2011. Diversity and regeneration statut of woody species in Tara Gedam an Abebaye Forests, North-Western Ethiopia. *Journal of Forestry Research*, 22 : 315-328.

[39] Mamah M., Baye-Niwah C., Hamawa Y., Dangai Y., Oumarou Z., Abdoulaye H., Mal Ali, Fawa G. & Mapongmetsem P.M. (2019). *Borassus aethiopum* Mart. Agroforestry parklands and climate change mitigation in Cameroon. *International Journal of Agriculture and Environmental Research*, 05(04) :436-455.

[40] Mapongmetsem P. M., Nduryang J. B. N., Fawa G., Dona A., 2015. Contribution à la connaissance des produits forestiers non ligneux de la zone soudano-sahélienne du Cameroun. Kapseu C., Nzié W., Nso E., Silechi J., Ngomo H., (Eds). Biodiversité et changements globaux: valorisation des effluents des industries, des résidus agro-pastoraux et forestiers. Actes du Colloque International du 21 au 23 juillet 2015 à Ngaoundéré, 139-147.

[41] Massaoudou M et Larwanou M., 2015. Caractérisation des peuplements ligneux des parcs à Faidherbia albida (Del) A.chev et à Prosopis africana (Guill., Perrot et Rich) Taub du Centre-Sud Nigérien. *Journal of Applied Biosciences*, 94 : 8890-8906.

[42] Morou B., Oumani H., Abdoulaye A.O., Diouf A., Guero C et Mahamane A., 2016. Caractérisation de la structure démographique des ligneux dans les parcs agroforestiers du terroir de Dan Saga (Aguié, Niger). *Int.J.Bioch.Chem.Sci*, 10 (3) : 1295-1311.

[43] Ousmane L.M., Oumarou B.G., Morou B., Karim S., Mahamane A., 2017. Etat de végétation ligneuse au Sahel : cas de Guidon Roumdji au Sahel Central du Niger. *Journal of Animal & Plant Sciences*, 31 (3) : 5033-5049.

[44] Idrissa B., Soumana I., Issiaka Y., Ambouta J.M.K., Mahamane A., Saadou M et John C.W., 2018. Trend and structure of population of Balanites oegyptiaca in parkland agroforestry western Niger. *Annal Research & Review in Biology*, 22 (4) : 1-12.

[45] Amani A., 2016. Croissance et potentiel de séquestration de carbone de quatre espèces de *Combrétacées* en zone Sahélienne et Nord-Soudanienne au Niger (Afrique de l'Ouest). Thèse de Doctorat en Biologie et écologie végétale, Université Abdou Moumouni de Niamey, 184p.

[46] Daget P., 2006. La biodiversité stationnelle et régionale : retour sur les concepts et les mesures. In : la biodiversité végétale : des plantes pour l'avenir. Actes du colloque de Troyes, pp. 13- 15

[47] Pindi K.C., 2016. Perception paysanne à l'intégration des espèces arborescentes dans les champs agricoles du Territoire de Tshala/Kongo-Central en RDC. Thèse présentée en vue de l'obtention du Diplôme de Master of Science (MSc) en Agroforesterie et optimisation des services écosystémiques des espèces naturelles et cultivées du bassin du Congo. Faculté des Sciences, Université de Dschang, Cameroun, 105p.

[48] Ouedraogo O., 2009. Phytosociologie, dynamique et productivité de la végétation du Parc National d'Arly (Sud-Est du Burkina-Faso). Thèse de Doctorat de l'Université de Ouagadougou, 188p.

[49] Savadogo O.M., Ouattara K., Pare S., Ouedraogo I., Sawadogo K.S., Barrou J et Zombre P., 2018. Structure, composition spécifique et diversité des ligneux dans deux zones contrastées en zone Sahélienne du Burkina-Faso. *Vertigo*, 16 (1), *URL : http://vertigo.revues.org/17282*

[50] Mahamane A, 1997. Structure, fonctionnement et dynamique des parcs agroforestiers dans l'ouest du Niger. Thèse de Doctorat 3ème Cycle, Faculté des Sciences et techniques, Université de Ouagadougou Bukina Faso.

[51] Mahamane A., Ichoua I., Ambouta J.M.K., Saidou M., Morou B., Amani I., Hango M., D'Herbes J.M., Gineste P., Wata I et Abassa T., 2007. Indicateurs écologique de la période optimale de remise en culture des jachères au Niger. *Sécheresse*, 18 (4) : 289-295.

[52] Arouna O., Etene C.G., Issiako D., 2016. Dynamique de l'occupation des terres et l'état de la flore et de la végétation dans le bassin supérieur de l'Alibori au Benin. *Journal of Applied Biosciences*, 108 : 10531-10542.

[53] Gockowski J., Tchatat M., Dondjang J.R., Hietet G & Fonda T., 2010. An empirical analysis of the biodiversity and economic returns to cocao agroforests in Southern Cameroon. *Journal of Sustainable Forestry 29* : 638-670.

[54] Kpangui K., Vroh B.T.A., Gona B.Z.B & Adou Yao C.Y., 2015. Diversité floristique et structurale des Cacaoyères du V Baoulé : cas de la Préfecture de Kokumbo Centre, Côte d'Ivoire. *European Scientific Journal* 11(36) : 40-60.

[55] Cissé A., Aka J.C.K., Kouamé D., Vroh B.T.A., Adou Yao C.Y & N'guessan K.E., 2016. Caractérisation des pratiques agroforestières à base cacaoyers en zone de forêt dense semi-décidue : cas de la localité de Lakota (Centre-Ouest, Côte d'Ivoire). *European Scientific Journal 12 (21) :* 50-69.

[56] Dodorom T. W., Fawa G., Hamawa Y., Oumarou H. Z., Dangai Y., Ibrahima A., Mapongmetsem P. M.., 2023. Characterization and Carbon Sequestration Potential of Sahelian Agroforestry Parklands of Chad. *Science Development*, 4(1): 1-11.

