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Biological diversity of agroforestry species in the socioeconomic context of producers in the Barh-kôh Department, Southern Chad: Case of Kissimi, Mayelé and Badara villages

Guiguindibaye MADJIMBE[1*], Touroumgaye GOALBAYE[1], Mbatbral NASKIDA[2], Senghor MAINKETE[3] and Bansedi NGARIKLA[4]

[1]Department of the Environment, Faculty of the Agronomic Sciences and the Environment, University of Sarh, BP 105 Sarh, Chad.
[2]Department of Land Planning, Faculty of Arts and Human Sciences, Ati University of Science and Technology, BP: 20 Ati, Chad.
[3]Laboratory of Applied Zoology, Department of Biological Sciences, Faculty of Sciences, University of Ngaoundere, BP: 454 Ngaoundéré, Cameroon.
[4]Department of Biology and Geology, Faculty of Science and Technology (FAST), Sarh University, BP: 105 Sarh, Chad.

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This study aims to better understand the woody biodiversity and the relationship between the state of tree cover in the Agroforestry Park and the management units, and also to know the socio-economic role played by the trees of the parks. The study was conducted in 3 villages in Barh-kôh Department, Chad, between May and November 2018. A plot of 2500 m^2 has been materialized in each management unit and the species found there are inventoried. Average per hectare is 37 feet in the bush fields, 27 feet in the village fields and 23 feet in the box fields. The study showed a cut rate of 87% among the wealthy classes against 82% among the poor. Tree cutting is more important in hut fields where only 5% of trees are spared. This study shows that agroforestry seems to be the technique conducive to the conservation of ligneous diversity. By virtue of its environmental and socio-economic contributions, this traditional agricultural practice could be part of the logic of sustainable agriculture. Also, by building the agroforestry parks, they will endow the agrarian systems with wood production capital with multiple associated functions.

Key words: Biodiversity, conservation, agricultural practice, sustainable agriculture, Chad.

INTRODUCTION

Due to the strong human pressure on natural environments, agroforestry systems around the world are today both a technique for conserving biodiversity and meeting the socio-economic needs of populations (Gone,

*Corresponding author. E-mail: anandhapriyan@gmail.com.

2013). Biodiversity and more precisely its plant component is recognized as a living heritage common to all humanity (Manfo, 2013). However, it is nowadays subject to erosion and transformations engendered by forms of development that are more and more incompatible with its preservation. In Chad, like most countries in Sudano-Sahelian Africa, the farming land system integrates trees scattered in the fields. This system has always allowed good land use in an environment where the use of mineral fertilizers remains very limited. But this agriculture, and more specifically slash-and-burn agriculture, is considered to be the main factors responsible for more than 70 to 90% of forest cover losses in Chad (ONDR, 2012). This situation challenges everyone to behave more responsibly in the use of the goods that nature offers us and that we must also bequeath to our children (Bambara et al., 2018). It is in this sense and to draw the attention of all to the uncontrolled use of natural resources that can lead to a situation of non-return, that the international community adopted the Convention on Biological Diversity in 1992. In the framework of its implementation, a national strategy and a plan of action on biological diversity has been elaborated at the national level because, it is in the synergy of action that the battle against the degradation of plant resources, the desertification by the deforestation, and for the safeguarding of biological diversity can be won. There is also evidence that today, with population growth and the growing need for agricultural land, biodiversity and the number of trees saved during clearing is decreasing. Agroforests according to Jagoret (2011) are generally characterized by a dominant stand, the main source of income or use (*Vitellaria paradoxa, Parkia biglobosa, Amblygonocarpus andongensis, Tamarindus indica*, etc.). These agroforests, in fact, are conservative of a certain level of biodiversity, up to a level close to that of secondary forest according to the systems of Tayo (2014) cited by Manfo et al. (2015). In the Barkôh Department, agroforestry has several advantages depending on the types of agricultural development. To this end, woody species should be inventoried in the different management units taking into account the socio-economic categories of the park operators and assessing the impacts on the conservation of biodiversity.

MATERIALS AND METHODS

The study material consists of farmers and the fields of some producers to check the density of trees per hectare. Tools such as forms developed for primary data collection were used.

Study site

The study was conducted in the Barh-kôh Department, specifically in 3 villages: Kissimi, Mayelé and Badara. In this area agroforestry seems to play an important role in the dynamics of plant communities and biodiversity. The Barh-kôh Department covers an area of 17,258 km^2 in southern Chad, between 8° 30'00 '' and 10° 30'00 '' North and 17° 30'00'' and 18° 30'00' 'East (Figure 1). It includes 5 sub-prefectures, 9 cantons and 435 villages, with a population of about 319,087 inhabitants, largely of sedentary origin (INSEED, 2014). The climate is tropical with alternating rainy season and dry season with an average duration of six months each. Located in the Sudanian zone, it has a rainfall ranging from 900 to 1,200 mm per year and an annual average of 983 mm. The average annual temperature is 27.6°C with extreme of 25 and 32°C. Hydrography is characterized by permanent rivers such as Chari, Bahr-koh, Bahr Sara, Bahr Keita and Bahr Aouk rivers, which are the main suppliers of fish in the region (Guibert and Kakiang, 2011). The vegetation consists of an important forest mass comprising three types of formations: open forests, tree savannas and shrub savannas (WFP, 2012).

Collection of data

Three types of management units were identified based on their position relative to the family enclosures.

Data collection

Three types of management units were identified based on their position relative to the family enclosures (Figure 2). The village field (CDV) is located after the box fields (Figure 3). The bush field (CBD) is completely outside the village (Figure 4), usually between 2 and 15 km from the dwellings.

Identification Operator and units

For each household, data likely to influence the management of the fields with an impact on agricultural production and the use of trees were considered, during our interview with the farmers. These are active or inactive persons (men, women, and children) in the household and the level of education of the head of the household. For each farmer, information on his identity and on the trees of the fields was collected.

Choice of farmers

In each village, the farmers were grouped into 3 classes of prosperity namely the poor, the well-off and the prosperous according to criteria of prosperity defined by themselves. The choice of operators for the woody inventory in the agroforestry parks took into account the prosperity class and the type of management unit. For each village, a sample of 9 farmers was taken; that is, 3 farmers per prosperity class. Each selected operator should have 3 types of management unit.

Inventory

In each management unit (field), a square plot of 50m x 50m has been materialized and the species found there are inventoried. The data are collected on an inventory sheet with measurements made on each species (circumference at 1.30 m or at the base, number of strands) and other information on the condition of the foot considered. The biodiversity of woody species has been determined using the Shannon-Wiener Index, which is used to assess species diversity and abundance in a given area. The index has the formula:

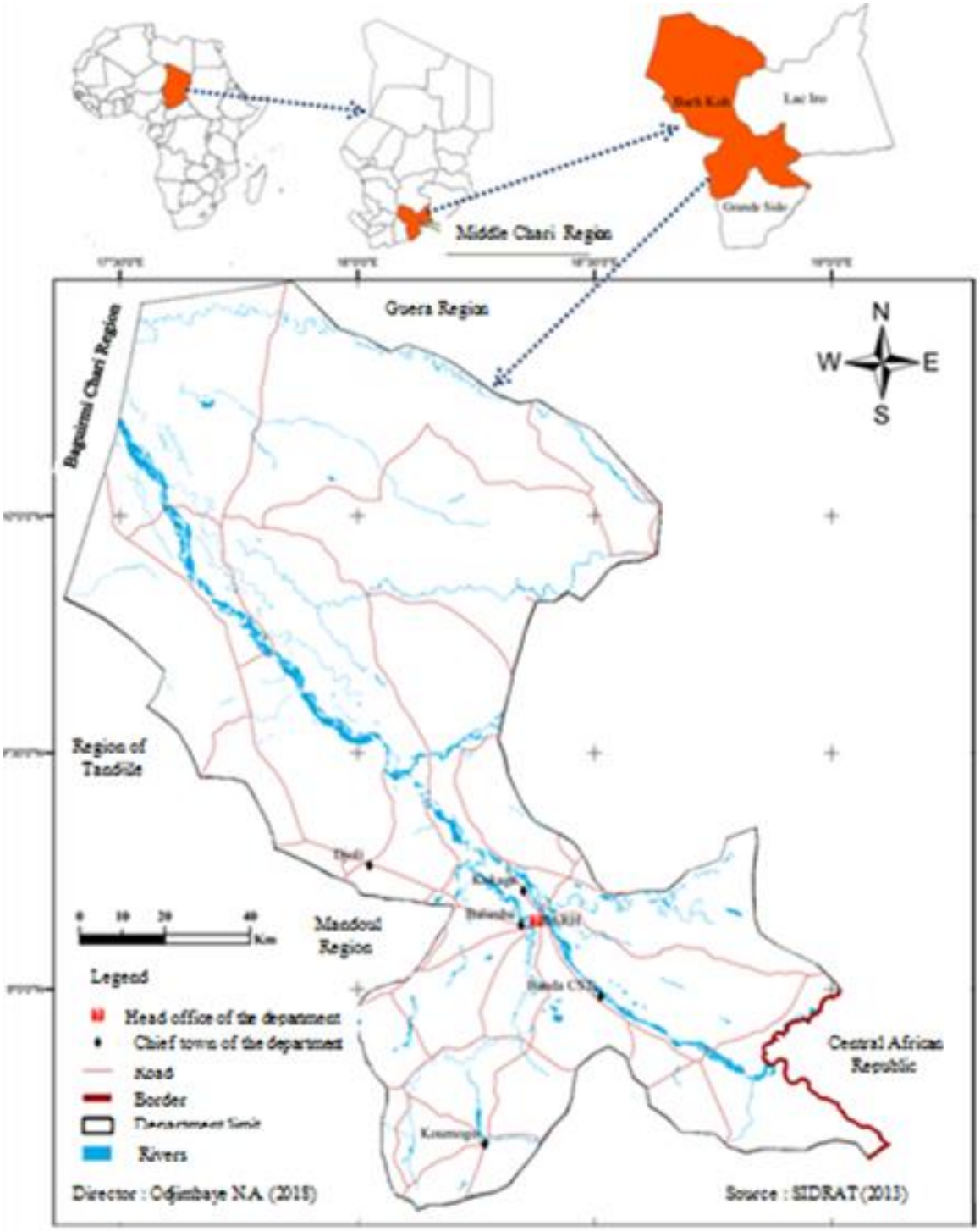

Figure 1. Geographic location of the study environment.

$$H' = \sum_{i=1}^{S} Pi * \log Pi$$

Where Pi represents the proportional abundance of a species and is calculated as: Pi = ni / N where ni = number of individuals of the species in the sample and N = total number of individuals of all species in the sample; S = total number of species. The statistical analysis was performed using a two-factor ANOVA (factor 1: management unit, factor 2: village). In the presence of a significant difference between different types of management units or between villages, comparisons were made using the test of the

Figure 2. Box field.

Figure 3. Village field.

smallest significant difference.

Non-measurable information is coded as follows: Cut level: 0 = not cut; 1 = <50%; 2 => 50%; 3 = totally cut; Attack level: 0 = not attacked; 1 = <50%; 2 = 50-75%; 3 => 75%. Biological type: GA = large tree, H> 14 m; A = Height tree between 7 and 17 m; PA = Small Tree, individual height H between 4 to 7 m; Ar = shrub, woody individuals of height H <4 m single-celled; Ab =Shrub, ligneous individual of height H <4 m polycaule. Sanitary state: S = healthy; M = Death; At = Attacked; Cp = Cut. Origin of the tree: Se = Sowing; R = Rejection; D = Drageon. An observation column made it possible to note for example the nature of the attacks or the cause of the mortality of an observed tree. The 2007 Excel spreadsheet was used to produce graphs illustrating the results of the research.

Figure 4. Bush field.

Table 1. Biodiversity of woody species by management unit in each of the three study cities.

Town	Prosperity level	Management unit		
		CDC	CDV	CDB
Kissimi	Deprived	1.0188±0.0805[a]	1.0175±0.0839[b]	1.0502±0.1012[a]
	Easy	0.1264±0.1036[b]	1.0306±0.0630[b]	1.3747±0.1077[b]
	Prosperous	0.8265±0.0660[c]	1.0219±0.0775[b]	1.5048±0.0402[b]
Mayelé	Deprived	0.1148±0.1056[b]	1.3278±0.0327[a]	1.0487±0.0455[a]
	Easy	0.1317±0.1210[b]	1.0512±0.0633[b]	1.0672±0.0711[a]
	Prosperous	0.7317±0.0786[c]	1.3013±0.0442[a]	1.0521±0.0468[a]
Badara	Deprived	0.0187±0.0712[a]	1.3415±0.0530[a]	1.9516±0.0263[a]
	Easy	0.1326±0.1530[b]	-	1.9815±0.0512[a]
	Prosperous	0.7108±0.0526[c]	-	1.8518±0.0346[a]

The values associated with the same letter are not statistically different from each other at the 5% threshold. CDC = Box field, DCV = Village field, CDB = Bush field.

RESULTS

Biological diversity of agroforestry species according to the management unit and the prosperity class

The analysis of variance on biodiversity calculated from the Shannon-Wiener Index revealed the existence of statistically significant differences between villages ($p < 0.0001$), as well as between management units. Contrast analysis revealed significant differences between the management units for two villages (Mayelé and Badara) out of three ($p < 0.0001$, $p < 0.0004$ in the case of Badara village) (Table 1). Table 2 gives the result of the distribution of trees per hectare according to the type of field and the standard of living of the farmer. Figure 5 shows the biological spectra of woody biodiversity in the different management units (Figure 5a: box field, Figure 5b: village field, Figure 5c: bush field).

Specific diversity in parks by level of prosperity and by village

Table 3 shows the distribution of trees by prosperity class. Dynamics of agroforestry species encountered in the different management units. The results on the dynamics of agroforestry species encountered in the

Table 2. Distribution of trees per hectare according to the type of field and the standard of living of the farmer.

Villages	Prosperity levels	Management unit			Average
		CDC	CDV	CDB	
Kissimi	Deprived	0	42	48	**45**
	Easy	0	42	49	**46**
	Prosperous	0	0	48	**48**
Average		**0**	**42**	**48**	
Mayelé	Deprived	7	38	52	**32**
	Easy	42	20	28	**32**
	Prosperous	21	24	32	**26**
Average		**23**	**27**	**37**	
Badara	Deprived	0	0	36	**36**
	Easy	0	0	19	**19**
	Prosperous	0	0	30	**30**
Average		**0**	**0**	**28**	

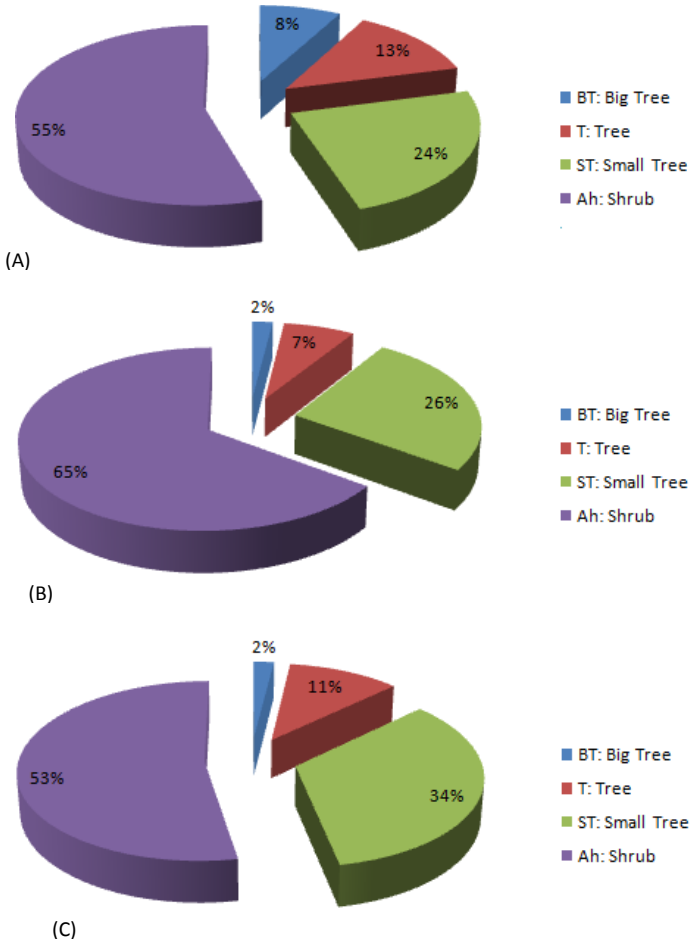

Figure 5. Biological types of trees by management unit (a) Biological types (box field), (b) Biological types (village field) and (c) Biological types (bush field).

Table 3. Distribution of trees encountered.

Village	Prosperity level		
	Deprived	Easy	Prosperous
Kissimi	16	12	10
Mayelé	14	11	8
Badara	6	5	9

Table 4. Distribution of trees by management unit in Kissimi.

N°	Tree species	Management unit					
		CDC		CDV		CDB	
		Adult	Rejection	Adult	Rejection	Adult	Rejection
1	*Acacia ataxacantha*	0	0	0	1	2	3
2	*Acacia senegal*	0	0	0	4	3	3
3	*Acacia seyal*	0	0	4	6	12	6
4	*Anogeissus leiocarpa*	0	0	0	0	1	0
5	*Balanites aegyptiaca*	0	0	8	7	9	26
6	*Combretum collinum*	0	0	1	1	0	0
7	*Combretum glutinosum*	0	0	1	0	0	0
8	*Combretum molle*	0	0	0	0	1	1
9	*Crateva adansonii*	0	0	1	0	0	0
10	*Diospyros mespiliformis*	0	0	0	0	1	3
11	*Guiera senegalensis*	0	0	0	1	0	0
12	*Lannea barteri*	0	0	6	0	2	0
13	*Piliostigma reticulatum*	0	0	1	1	6	22
14	*Sclerocarya bieria*	0	0	2	0	0	0
15	*Tamarindus indica*	0	0	0	0	1	0
16	*Vitellaria paradoxa*	0	0	0	0	1	0
17	*Ziziphus mauritiana*	0	0	0	4	1	26
18	*Ziziphus mucronata*	0	0	0	0	0	1
	Total	**0**	**0**	**24**	**25**	**40**	**91**

different management units are presented in Tables 3 to 6. Cutting level, mortality and tree attack: the tree cutting rate is 87% for the wealthy and 82% for the poor. In the management units, only 5% of the trees are spared. Tree attacks were also observed.

Socio-economic conditions of the farmers

Table 7 establishes the social burden of the farmers in the three villages in relation to the identified prosperity classes.

DISCUSSION

Biological diversity of agroforestry species by management unit and prosperity class

In each of the two villages where significant differences were observed, it is in the case of fields where the biodiversity is the lowest (Table 1). The diversity of species and abundance of individuals within each species combine to provide biodiversity indices that reveal a clear distinction between the different types of management unit. The distribution of the number of woody species between management units varies significantly between villages ($p < 0.0001$). In general, it is in the fields of box that the arboreal biodiversity is weakest. Thus, depending on the management unit and the prosperity class, it turned out that there is no longer a box office in Kissimi for all farmers and a village field for the prosperous class. The given reason is the subdivision of the land. Through this operation, the box fields have become residential plots that are being serviced. It is only at Mayelé that we are currently meeting all the management units. Depending on the management units, more trees are found in the bush fields than in the village fields, which in turn have more trees than the box fields when all three types exist. In Kissimi, where there are

Table 5. Distribution of trees by management unit in Mayelé.

N°	Tree species	Management unit					
		CDC		CDV		CDB	
		Adult	Rejection	Adult	Rejection	Adult	Rejection
1	*Acacia ataxacantha*	2	0	2	0	0	0
2	*Acacia senegal*	0	0	0	0	0	4
3	*Acacia seyal*	0	0	1	0	2	3
4	*Acacia sieberiana*	0	4	2	9	6	5
5	*Balanites aegyptiaca*	1	0	5	8	22	32
6	*Combretum collinum*	0	0	0	0	1	0
7	*Combretum fragrans*	0	0	0	0	0	1
8	*Combretum glutinosum*	0	0	0	0	0	1
9	*Faidherbia albida*	0	0	8	1	4	1
10	*Guiera senegalensis*	0	0	1	0	0	1
11	*Hyphaene thebeica*	3	0	5	2	0	2
12	*Maerua crassifolia*	0	0	1	0	0	0
13	*Piliostigma reticulatum*	0	0	0	0	1	0
14	*Piliostigma thonningii*	0	0	0	1	0	0
15	*Sclerocarya bieria*	0	0	3	4	3	0
16	*Ziziphus mauritiana*	0	1	2	17	0	9
	Total	**6**	**5**	**30**	**42**	**39**	**59**

Table 6. Distribution of trees by management unit in Badara.

N°	Tree species	Management unit					
		CDC		CDV		CDB	
		Adult	Rejection	Adult	Rejection	Adult	Rejection
1	*Acacia ataxacantha*	0	0	0	0	0	1
2	*Acacia senegal*	0	0	0	0	1	1
3	*Acacia sieberiana*	0	0	0	0	10	7
4	*Balanites aegyptiaca*	0	0	0	0	32	6
5	*Combretum fragrans*	0	0	0	0	0	2
6	*Combretum glutinosum*	0	0	0	0	2	0
7	*Faidherbia albida*	0	0	0	0	1	2
8	*Maerua crassifolia*	0	0	0	0	2	0
9	*Prosopis africana*	0	0	0	0	1	0
10	*Ziziphus mauritiana*	0	0	0	0	0	1
	Total	**0**	**0**	**0**	**0**	**49**	**20**

only two types of field, there is an average of 48 hectares in the bush fields and 42 in the village fields. In Mayelé, 37, 27 and 26 trees per hectare were inventoried in the bush fields, village and hut respectively. On the other hand, the work of Abegg et al. (2006), on the socio-economic factors influencing the woody biodiversity of agroforestry parks in two villages of the central plateau in Burkina Faso, showed an increase in biodiversity from village dwellings. However, no significant influence on biodiversity has been observed in relation to a farmer's prosperity class. Considering the standard of living of the farmers, the woody diversity of the parks differs from village to village. At Kissimi, if the density of trees per hectare is greater among the prosperous and less among the poor, at Mayelé and Badara, it is the contrary phenomenon, they are more ligneous in the fields of the poor than the prosperous ones. Subsequent studies (Pounakoumna, 2017; Madjimbe et al., 2018; Ngoh-allah, 2018) had shown the existence of three types of fields in Kissimi and Mayelé, and only bush fields in Badara because of the extension of the Chari River at the expense of agricultural areas and the importance of lifting

Table 7. Household burden by prosperity class.

Class	Number of people in the family			
	Assets	Inactive	Total charge	Children
Deprived	61	17	**78**	39
Collateralised	58	16	**74**	24
Prosperous	57	26	**83**	39

with the omnipresent animals around the concessions. Figure 5 shows that biological spectra of woody biodiversity in the different management units show only three biological types in the box fields and five types in the village and bush fields. In the box or village fields, the dominant stratum consists of shrubs (Karembe et al., 2014), whose height is generally less than 4 m, and a few large trees (9%) are the authors of the concessions. In the bush fields, it is the individuals between 4 and 7 m high that form the largest stratum.

Specific diversity in parks by level of prosperity and by village

In the majority of cases, the poor have more plant species in their fields than the rich or prosperous, so this is a situation that needs to be encouraged. This is the case in Kissimi with 16 species among the poor, 12 among the rich and 10 among the prosperous. In Mayelé, we find in the same order 14, 11 and 8 species. Although the differences are not so clear as can be seen, the tendency for the poor to keep more plant species is noticeable. The use of different parts of the trees for feeding, especially during the lean season, may explain the option of the poor to diversify the species in their fields (Guibert and Kakiang, 2011). In Badara, the situation is different, as the prosperous keep more species than the other two classes. In this village, livestock is the main activity and forage research for animals can explain the interest in keeping various species.

Dynamic agroforestry species encountered in different management units

In bush fields like those in the village, there is a predominance of discards on adults. In Kissimi, it is especially in the bush fields that the rejection rate is very appreciable compared to that of the village fields. By species, *Balanites aegyptiaca, Ziziphus mauritiana and Piliostigma reticulatum* have higher rates of regeneration than other species. In Mayelé, however, species such as *Vitellaria paradoxa, Tamarindus indica, Sclerocarya bieria, Anogeissus leiocarpa or Lannea barteri* do not show discards to ensure succession. The regeneration situation according to the management unit is similar to that of Kissimi. There are more rejections in the bush fields than elsewhere. By species, *Balanites aegyptiaca* and *Ziziphus mauritiana* have more discards than other inventoried species. Unlike Kissimi and Mayelé, in Badara there are more adult trees than rejections in the only management unit, the bush field. These results are consistent with the findings of Carriere (2002) who worked on ancestral agricultural practice in the service of forest regeneration. The same author has indicated that for all species, the rate of regeneration is low hence the succession of woody in the parks is very compromised.

Cutting level, mortality and attack of trees

The cutting of trees is observed in all classes, wood being the only source of energy in the village. Even wealthy people do not use gas. Demand for wood is higher among the wealthy classes and explains the high cut rate (87%) compared to the poor (82%). In comparison to the management units, tree cutting is more important in the box fields where only 5% of the trees are spared. It is in the village fields that the cut is less felt. The causes of tree cutting are multiple. Regarding the trees of the fields, the cuts are made for the manufacture of working tools like the house or to make mortars and pestles. At the harvest time, farmers lop some big feet to reduce the volume of their crowns. Indeed, it seems that the trees with big crowns attract the birds pests cereals. According to Bamba et al. (2010), the size of the crowns reduces the number of birds on the trees, which limits the damage. The uprooting of trees by the wind and the intensity of the cuts are the most important cause of tree mortality. The attacks are caused by termites, fungi, locusts, ants or other plants such as *Leptadenia hastata* which sometimes envelops all the host's crown and thus hinder its normal development.

Socio-economic conditions of the farmers

In terms of human capital, we note that the three classes have almost the same potentialities. This complicates the situation for the underprivileged class, faced with feeding the same number of mouths as the wealthy and prosperous, which only widens the gap between the poor

and the rich. We find that the prosperous have more inactive people in their charge and fewer active arms than the other two classes. To agree with Vroh et al. (2010), it can be concluded that the child is considered as a source of wealth and motive for consolation. This explains why the poor have as many children as the prosperous ones to make up for their economic shortfall.

Conclusion

The inventory of woody species in the different management units takes into account the level of prosperity of the farmers. This makes it possible to rule on the relationship that may exist between the ligneous diversity of the agroforestry parks, the level of prosperity of the farmers and the units of management. In terms of species diversity, there is a higher number of species in the fields of the poor in Kissimi and Mayelé. In Badara, a village where livestock is the main activity of the population, the wealthy class keeps more species in the fields than the poor. In terms of the number of individuals, the woody diversity of the parks according to the level of prosperity also differs from village to village. In Kissimi, there are more trees in the fields of the prosperous while in Mayelé and Badara it is the opposite phenomenon. Depending on the management units, there is clearly a predominance of plant biodiversity in bush fields compared to village fields.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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