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FARMER MANAGED TREE NATURAL REGENERATION AND DIVERSITY IN A SAHELIAN ENVIRONMENT: CASE STUDY OF MARADI REGION, NIGER

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ABSTRACT
A study on tree diversity in farmer's fields was conducted in 3 village territories in Maradi region in Niger following a north-south rainfall gradient. These villages belong to pastoral, agropastoral and agricultural zones and are located in phytogeographical sectors central north-Sahelian, south – Sahelian and central north – sudanian. Phytosociological investigations coupled with farmer's survey were carried out in the village territories. Interviewed farmers stated that household disposal of fire and service wood, income generation, desertification control, fodder, and soil fertility replenishment are the prime movers for adopting farmer managed tree natural regeneration. Results from this study showed that more than 80% of adult trees are shrubs. The sprouts and other young trees are dominant for about 69%; wood volume and tree covers rank high in the south –Sahelian sector. The tree populations comprise about 80% of healthy individuals and only 4% are cut. The number of species increases significantly ($p<0.01$) from north to south and varies from 28 to 37 species. Characteristic species of each site are presented. Rainfall and applied sylvicultural operations and uses are key factors that favor tree diversity in all sites.

KEYWORDS: Trees on farm, Farmer managed tree natural regeneration, tree diversity, specific contribution, Maradi, Niger, Sahel

INTRODUCTION
For many decades, Sahelian ecosystems followed strong modifications due to climate change process and human activities (Larwanou and Saadou, 2011). These transformations translate a manifest degradation of tree and herbaceous vegetation which are of high importance for local populations.

Maradi region, like other parts of the country is experiencing disturbance of its climatic conditions that impact people's livelihoods (SDR, 2002). For instance, a study conducted at regional level by the University of Bordeaux showed that as earlier as 1977, agricultural pressure on land and a progressive limitation of natural resources constitute a phenomenon with more or less intensity on agricultural communities in the region (Koechlin, 1977). Surveys on disappeared or threatened forest species in this region showed impacts of low rainfall in the disappearance of many tree species (Larwanou, 1998).

To overcome this situation, local populations in Maradi region have developed adaptative and mitigation strategies to contain environmental problems on their productive activities. They preserve in their farms some tree species (Mahamane, 2001 ; Larwanou, 2005); the selection of species is done through existing floristic

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diversity that add values to them (Larwanou et Tougiani, 2008) ; this way of doing has led to the development of a technique known as farmer managed tree natural regeneration (FMNR).

Farmers in this part of the country have adopted massively this technique (Marou et all, 2002). Various studies conducted in this region have shown that a regreening is taking place because of rehabilitation efforts carried out by various actors among which farmers through assisted natural regeneration (Olsson et al, 2005 ; Larwanou and Saadou, 2006 ; ICRISAT, 2006; Larwanou et al, 2006, Larwanou and Saadou, 2011). These various studies have shown that this regreening is more perceived in farmers` fields. Farmers' involvement in preserving trees in their farms could constitute avenue in understanding the drivers of this regeneration.

MATERIALS AND METHODS

Ecological characteristics of Maradi region

The actual vegetation was woodland with an under storey composed of Combretaceae. According to Raynaut et *al*. (1988), the physionomic type varies with climatic gradient and geomorphological situations. Saadou (1990) distinguished 3 phytogeographical compartments in this zone: i) *Central North-Sahelian C2*, ii) *Central South-Sahelian compartment B2* and iii) *Central North-Sudanian compartment A2.*

The rainfall zonation in Maradi region gives the following 3 agroecological sectors:
The pastoral zone is characterized by a large fragility due to the rainfall spatio-temporal irregularity and a low population density (less than 20 inhabitants per km²). It has a pastoral vocation but agriculture is not totally absent even though the climatic risks limit agricultural investment.

The agropastoral zone in which agriculture and livestock husbandry constitute the dominant production systems. Millet, sorghum and cowpea are the main crops. Most of the villages are recent with a mean population density of 80 inhabitants per km². Land pressure is a major constraint that leads to reduction of fallow duration and consequently low soil fertility.

The agricultural zone is characterized by human pressure on lands with a population density approximating 100 inhabitants /km². This pressure has led to land blocking and a significant reduction of tree cover. Despite the absence of pasture lands, animal husbandry is practiced by local community. According to Yamba (2000), the tree stand is relatively old in this zone and the diversification of productions is much oriented towards the emergence of extra-agricultural activities. The integration in market economy that started with the colonial period has led to the development of cash crops and groundnut in particular.

Study sites

The study was conducted in three village territories corresponding to the above phytogeographical and agroecological sectors from north to south of the region with one village by sector. The ethnic group is Hausa in the three sites. Rainfall gradient is therefore the determinant factor in village selection. The selected villages are:

Koda: located in the extreme north of Maradi in the pastoral zone in the rural commune of Tagriss, with 4°29'52'' N and 7°31'14'' E, and is in between 200 and 300 mm isohyets. The population has 63 households and is composed of Hausa and touaregs according to village chief. The climate that characterizes this zone is sahelo-saharian type with two distinct seasons: a long dry season and a short rainfall season with a mean annual temperature varying between 30 and 33°C.

Batchaka: located in the center of Maradi region, this village belongs to the agropastoral zone between 300 and 400 mm. with 13°45'54'' of latitude North and 07°21'26' of longitude Est. The population is Hausa in majority and is composed of 72 households. Agriculture and animal husbandry are the main activities of the population. The animal husbandry is semi-intensive and pasture lands are mainly fallow lands. The climate is characterized by a long dry season from November to May and a rainfall period from June to September with rainfall averaging that of the region.

Moulmouchi: located in the agricultural zone and in the extreme southern part of the region, between latitude 13°11'10'' N and longitude 07°01'20'' E and between isohyets 400 and 500 mm with a population in majority Hausa with 83 households. The climate is sudano-sahelian with a long dry season from November to May and a rainfall season from June to September. The mean annual temperature varies from 22°c in cold period and 39°c in hot season. The vegetation is composed of Combretaceae on dunes and *Acacia spp* in the Goulbi valley. Some species like *Vitellaria paradoxa, Diospyros mespiliformis, Tamarindus indica* and *Hyphaene thebaica* are dispersed along depressions.

Farmers selection and tree diversity
In each village, 9 households head farmers were chosen randomly for this study.

Various methods of phytosociological investigation have been used in tree vegetation studies in the Sahel. These are floristic list of species for establishing ecological profile (Ali, 1997), principal phytosociological characters (Baina, 2000), biological types of Raunkiaer and the structure of vegetation (Larwanou, 1992). For this study, a combination of these methods has been used to obtain desired information.

Data collection was carried out during rainy season when tree species and other herbaceous species could be identified (Larwanou, 2005).

The inventory was carried out in the farms of selected individuals from the village outwards. The method is similar to the one adopted by Yamba (1994) and modified by Larwanou (2005). Therefore, an inventory in plots in the farms allows ascertaining the heterogeneity that exists in a given territory from the village outward. For the same ecological region, the analysis of data could help to distinguish the impacts of land use (duration, modes of exploitation and management) on the dynamic of existing resources.

Plots were materialized according to the configuration of the terrain in a given village territory in order to cover all land us types and the different existing physiographical units. In each farm, plots of 50 m x 40 m (2000 m²) were placed from the village according to the presence of farms for selected farmers. The size of 200 m² was chosen in order to compare the different land uses and physiographical units. This plot size (0.2 ha) allows a good comparison between studied ecosystems (Hall et Okali, 1979). The delimitation was done with a meter tape of 100 m and a GPS was used to delimitate farms.

In each plot, all tree species were identified and measured and the number of individuals was determined. Resprouts/seedlings and adult trees were counted separately for each species. Was considered as resprouts/seedlings, an individual for a given species with a total height less than 0.5 m and the diameter at 0.3 m above ground is less or equal to 3 cm. also, an individual is considered as adult when the above characteristics cannot be applied to it.

The following dendrometric parameters were measured:

- the total height of the big individual for all the individuals with height greater than 0.5 m ;
- the diameter at 0.3 m for all individuals with total height less than 1.30 m ;
- the diameter at 1.30 m for all individuals with total height greater than 1.30 m ;
- the number of resprouts was determined by stump;
- the mean crown diameter was measured to estimate the tree cover (%).

The plot number varied with farm area.
Attacks by illness, insects or animals were appreciated on field; *H* if the individual is healthy; *D* if the individual is dead; *At* if the individual is attacked; Ct if the individual is cut. The percentage of attacks estimated on field represents the rate of damages of each individual. The level of attack is codified as follows: 0 = no attack; 1 = 50%; 2 = 50 à 75 % and 3 = high attack > 75%.

The observation on the degree of cut was only done on adult trees. The codification was done as follows: 0 = no cut; 1 = <50%; 2 = > 50%; 3 = completely cut.

The biological types were annotated as follows : Bt : big tree H> 14 m; T : tree of H between 7 and 14 m ; St : small tree of H between 4 and 7 m ; Sh: shrub with H < 4 m monocaule ; Shy : shrubby with H < 4 m polycaule. All these characterized the height of trees at adult stage.

Also, in each village, farmers were interviewed on more preferred species, the principal uses of tree species as well as the threats to these species.

Data analysis
Collected data were analyzed with SPSS (Statistical Package for Social Sciences) for the following information:

Tree cover
Tree cover is the area of vertical projection of the tree crown on soil. Tree cover was estimated in plots by measuring the area occupied by projecting the tree crown on soil. The ratio of total areas covered by trees and total area inventoried gives the rate of tree cover on soil. It is calculated by the following formula: Tree cover = *(mean crown diameter) ² x ∏ (3.14)/4.*

Rate of regeneration
The rate of regeneration is the ratio of the total number of resprouts/seedlings and the total number of individuals in the stand. This is a key indicator for determining the stand regeneration capacity.

Diversity index
The specific diversity is defined by the number of species and individuals of each species (UICN, 2001). The diversity index of Shannon-Wiener (Shannon and Weaver, 1963) was used and is obtained as follows: SH'= - Σpilogpi

i=1

Where p_i is the proportional abundance or percentage of importance or specific frequency of each species. With p_i = ni/N where ni = number of individuals for a given species in the sample; N= total number of individuals for all species in the sample. The value of H' depends on number of species present, their relative proportion, the size of the sample N and the logarithmic base. This formula indicates that when H' is high, it indicates that the sample is rich in species.

Equitability index
The equitability or dominance is the ratio of observed diversity to completely equal frequency distribution. It was calculated following Pielou (1966):

E = *H /logS* where H = richness index and calculated as follows: *H= (S-1) / Ln N* with S = total number of species.

RESULTS
Farmers selection in the villages
The level of instruction is an important factor in understanding and adopting a given innovation. Among the 27 interviewed farmers in the three villages, 30 % have been to Coranic School, 7% attended primary school, 26% have done adult education and 37 % have no instruction.

The modes of land acquisition in the study sites are heritage, buying, borrowing and hiring. Heritage is the most important mode of land acquisition followed by buying which is only for less and averagely vulnerable persons who have more land capital.

In average, the land capital is more important in the pastoral zone than agropastoral and agricultural zones respectively in Maradi region. The number of inventoried farms is 22 in Koda (2.44 farms per household), 18 in Batchaka (2 farms per household) and 17 in Moulmouchi (1.9 farms per household).
In general, the populations migrate from north to south where climatic conditions are globally favorable leading to land pressure in the south especially in Moulmouchi.

Reasons for practicing farmer managed natural regeneration in farmers`field
The practice of farmer managed natural regeneration in agricultural lands was initiated by extension services and development projects. The main objectives were to combat desertification, ensure environmental protection, improve agricultural yield and for other goods and services (Table 1).

Table 1: Reasons for adoption of FMNR in the villages

Reasons	Proportion (%)		
	Koda	Batchaka	Moulmouchi
Provision of fire and service wood	33.33	25.92	29.6
Combating desertification	33.33	33.22	25.91
Improving soil fertility	29.62	33.22	25.91
Provision of fodder from trees	3.7	7.4	7.4
Provision of shade	0	0	7.4
Combating wind and water erosion	0	0	3.7
Total	100	100	100

The reasons for adopting FMNR are almost the same in the 3 villages (table 1). FMNR is necessary because it contributes to improving soil fertility (case of *Faidherbia albida*), human and animal food, pharmacopeia, artcraft, cording, and other utensils, but also as sources of domestic energy and construction materials.

The survey conducted showed that FMNR is practiced by all social categories in all the farms whatever the mode of acquisition and dimension.

Structure of tree stands

Tree distribution by diameter class

The distribution of tree stands by height class showed the vertical structure of trees in farmer's fields. In all the villages, the majority of trees are concentrated in the class 0 to 4 m up to 80% in terms of height (figure 1). The grouping of individual trees in this class showed that the dominant tree stratum is low shrub. The second class 4 to 7 m represents the high shrub strata with a proportion of 3.41% in Koda, 6.39% in Batchaka and 3.72% in Moulmouchi. The other classes7 to 14 m and above 14 m are not well represented except in Batchaka where the class 7 to 14 m is approximately 5%. This difference seems to be linked to the presence of *Faidherbia albida* and *Piliostigma reticulatum* which are species with high height and benefiting of possible protection by farmers because of their utility.

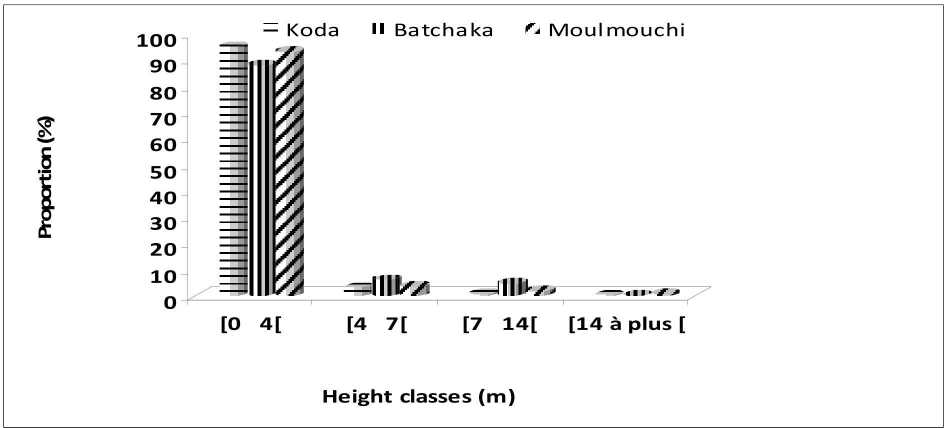

Figure 1: Distribution of trees by height class

The distribution of trees by diameter classes showed that more than 80% (figure 2) of trees are grouped in the class 0 to 10 cm.

The second class is 10 to 20 cm with a proportion between 5 and 7%. The classes of diameter greater than 30 cm are not well represented and are exclusively composed of *Faidherbia albida, Diospyros mespilliformis, Vitellaria paradoxa, Piliostigma reticulatum, Lannea acida and Tamarindus indica.*

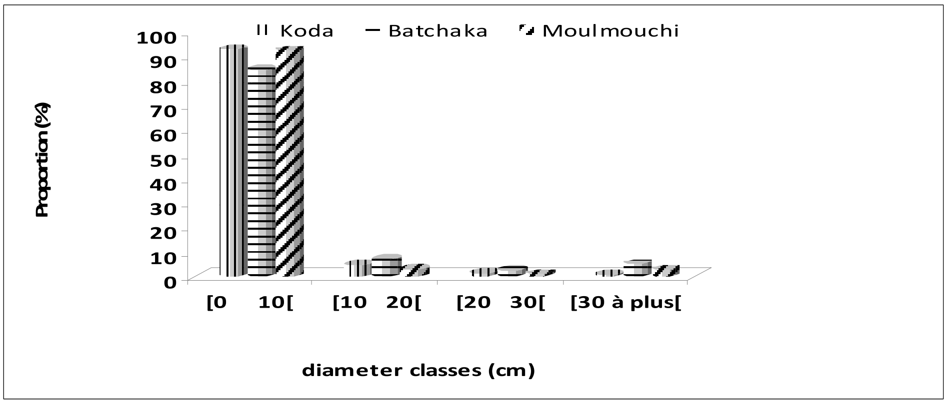

Figure 2: Distribution by diameter class of trees

Typology of trees

The shrubs are dominant up to 75% followed by shrubby and small trees. Trees and big trees followed (figure 3). Within a given site, this repartition differs; trees are dominant in Batchaka, Moulmouchi and Koda respectively. The small trees followed the reverse trend where they are dominant in Batchaka, Koda and Moulmouchi respectively.

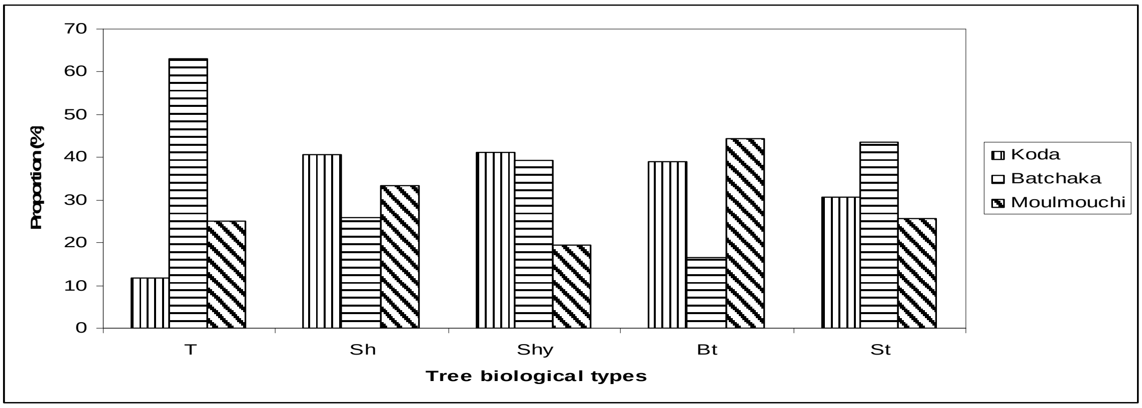

Figure 3: Proportion (%) of tree biological types in the villages

The resprouts/seedlings are more important than the adult individuals with 69.25 and 30.75 respectively in all the sites and within a given site (Table 2).

Table 2: Proportion (%) of adult individuals and resprouts/seedlings in the villages

Types of individuals	Villages			Total
	Koda	Batchaka	Moulmouchi	
Adult	34.61	42.96	13.22	30.75
Resprouts/seedlimgs	65.39	57.04	86.78	69.25
Total	100	100	100	100
	Distances from the village			
	1	2	3	
Adult	28.7	31.73	35,93	30.75
Resprouts/seedlimgs	71.3	68.27	64.07	69.25
Total	100	100	100	100

The numbers 1, 2 and 3 represent distances of farms from the villages1= near the village; 2 = averagely far and 3 = relatively far.

The number of adult individuals increases from village to the bush indicating that there are old individuals far from the village (Table 2). This is opposing the number of resprouts/seedlings with number greater close to the villages.

Volume and tree cover
The wood volume is important in Batachaka followed by Moulmouchi and Koda. The tree cover is important at Batchaka followed by Koda and Moulmouchi (Table 3).

Table 3: Volume (m^3) and tree cover (%) in the villages

Villages	Volume (m^3)		Tree cover (%)	
	Mean	SD	Mean	SD
Koda	0.007	0.026	11.218	0.354
Batchaka	0.023	0.021	26.804	1.878
Moulmouchi	0.019	0.024	7.433	0.234

SD: standard deviation

Health status of tree stands
The health status of trees has more than 80% of healthy individuals. Cutting of trees is minimal (5%) and attacks of all kinds (12%) (Table 4). This situation is variable within a given site. Attacks are more important in Koda and tree cutting more prominent in Moulmouchi.

Table 4: Health status (%) of trees in the villages

Health status	Koda	Batchaka	Moulmouchi	Total
At	16.34	2.94	16.74	12.45
Ct	5.63	3.04	7.95	5.56
H	78.03	94.02	75.31	81.99
Total	100	100	100	100
Level of attacks				
0	83.51	97.27	83.57	87.65
1	8.01	0.84	4.34	4.75
2	5.95	1.57	8.16	5.31
3	2.54	0.31	3.93	2.29
Total	100	100	100	100
Level of cutting				
0	94.69	96.96	92.15	94.9
1	0.08	0.1	0.2	0.5
2	0.87	0.21	2.9	1.3
3	4.36	2.73	4.5	3.3
Total	100	100	100	100

At = attack ; Ct = cut ; H = Healthy. 0 = no attack ; 1 = 50% ; 2 = 50 to 75 % and 3 =seriously attacked > 75%. 0 = no cutting ; 1 = <50% ; 2 = > 50% ; 3 = completely cut.

Where there are attacks, the degree varies from 2 to 5% (Table 4).
The degree of cut is minimal and varies from 0 to less than 4% (Table 4).

Characterization of tree biological diversity

Number of species and specific contribution

The difference is highly significant (p<0.01) among villages for the number of species (Table 5). The number of tree species increases from north to south. Nevertheless, this difference is not significant (p<0.05) with distance from village to the bush within a given village territory (Table 5). This low difference between sites according to distances could be due to the small land area of the territories.

Table 5: Mean total number of species by village and according to distances

Villages		Mean	SD	Significance
Koda	Village level	28	10	Pr<0.00
	1	28	10	Pr<0.78
	2	27	10	Pr<0.78
	3	30	10	Pr<0.78
Batchaka	Village level	33	13	Pr<0.00
	1	30	12	Pr<0.78
	2	34	13	Pr<0.78
	3	32	14	Pr<0.78
Moulmouchi	Village level	37	13	Pr<0.00
	1	40	10	Pr<0.78
	2	34	16	Pr<0.78
	3	33	13	Pr<0.78

In Koda, 4 species present each a specific contribution greater than 10% (Table 6). These are*: Calotropis procera* (*37.83%), Boscia senegalensis (20.14%), Guiera senegalensis (17.45%), Faidherbia albida (11.58%).* The less represented species are *Acacia nilotica, Acacia seyal and Azadirachta indica* (table 6). The more represented families are: Mimosaceae (6 species) and Capparidaceae (3 species), whereas the Asclepiadaceae, Combretaceae, Caesalpiniaceae and Rhamnaceae are represented by only 2 species and the other families (Anacardiaceae, Balanitaceae, Meliaceae and Burseraceae) are represented by only one species. Despite the climatic constraints, these species have adapted to the spatio-temporal irregularity of rainfall.

In Batchaka, 4 species have a specific contribution of more than 10% and are *Faidherbia albida (21.27%), Guiera senegalensis (21.07%), Piliostigma reticulatum (11.53%)* and *Calotropis procera (10.90%).*

The 3 first species represent 53.87% of the total number of individuals (Table 6). The less represented species are *Boscia angustifolia, Entada africana, Pterocarpus erinaceus, Tamarindus indica, Ziziphus spina-christi* representing 0.50% of the whole territory giving 0 .10% per species.

In the village species list, there is a dominance of Caesalpiniaceae (5 species), Mimosaceae (4 species) and Capparidaceae (3 species). The other families are represented by one or two species each.

In Moulmouchi, two species have a specific contribution of more than 10% (Table 6) and are *Piliostigma reticulatum (27.27%)* and *Guiera senegalensis (26.96%).* These species represent more than half of the total number of individuals (54.23%). The less represented species are *Acacia ataxacantha, Anogeïssus leiocarpus, Bombax costatum, Azadirachta indica, Boscia senegalensis, Calotropis procera, Combretum nigricans, Gardenia erubescens, Grewia bicolor, Sterculia setigera.*

Table 6: Specific contribution of first 10 species in the villages

Villages	Species	Frequencies (%)
Koda	*Calotropis procera*	37.83
	Boscia senegalensis	20.14
	Guiera senegalensis	17.45
	Faidherbia albida	11.58
	Maerua crassifolia	6.34
	Leptadenia pyrotechnica	1.19
	Combretum glutinosum	1.11
	Albizia chevalieri	0.95
	Balanites aegyptiaca	0.56
	Ziziphus mauritiana	0.56
Batchaka	*Faidherbia albida*	21.30
	Guiera senegalensis	21.09
	Piliostigma reticulatum	11.54
	Calotropis procera	10.91
	Annona senegalensis	9.23
	Combretum glutinosum	5.04
	Sclerocarya birrea	3.46
	Balanites aegyptiaca	3.36
	Albizia chevalieri	2.62
	Hyphaene thebaica	2.41
Moulmouchi	*Piliostigma reticulatum*	27.27
	Guiera senegalensis	26.96
	Albizia chevalieri	7.95
	Hyphaene thebaica	7.95
	Faidherbia albida	6.71
	Annona senegalensis	3.93
	Dichrostachis cinera	2.79
	Maerua angolensis	1.65
	Prosopis Africana	1.65
	Ziziphus mauritiana	1.65

Diversity index according to rainfall gradient
Table 7 showed that high number of species, high values of H', H and E. these results confirm that the species diversity is more important from south to north in the study sites.

In definitive, we can affirm that following the rainfall gradient, there is difference in terms of species diversity. Some species representative of some families like Rubiaceae, Tiliaceae, Sterculiaceae, Sapotaceae, Ebenaceae, Moraceae, Fabaceae and Moringaceae found in southern sites are not present in the north (Koda) whereas all the species inventoried in that particular site are found in Batchaka and Moulmouchi.

Table 7: Diversity and equitability indices in the villages

Diversity and equitability indices	Villages		
	Koda	Batchaka	Moulmouchi
H'	0.766	0.996	1.001
H	2.801	3.809	5.527
E	2.118	2.661	3.473

DISCUSSION

Tree biodiversity in the Sahel varies according to agroecological zones along rainfall gradient north - south and the number of species increases accordingly (Saadou, 1990). The protected and preserved species at village level by FMNR are diversified. The dominance of one species to another could be due to the regeneration capacity (Akpo and Grouzi, 1996) or to the benefits it procures to the farmers (Larwanou, 2005). The choice of species to be spared and protected in the farms is depend to a certain number of criteria like the capacity of the species to regenerate, the utility in terms of uses and provision of services (protection against wind, wood production, improvement of soil fertility and traditional pharmacopeia).

Individual trees density as well as their typology is also function of the above factors.
The local and regional rainfall interactions, the farmer management practices and the soil types have shown a direct relationship with the development of vegetation and biodiversity (Olsson *et al.* Zeng *et al.* 1999). Another explanation of the difference in diversity and density in agricultural territories could be due to improved land management which has given similar vegetation changes somewhere in the world (Runnstro, 2003).

Agricultural lands in the Sahel are characterized by regularly scattered trees. Tree species are planted or naturally regenerated and protected because of the utility of their products. In occasionally cultivated lands, far from the village, tree distribution is less regular and species less diversified (Henk and Jan-Joost, 1995; Larwanou, 2005).

In the present study zone, the density of species and tree cover in parklands vary considerably. There was less systematic studies in Sahelian parklands. The fewer studies that were carried out in parklands were done in sites which are relatively favorable and having dense and well developed stands. In the parklands, the tree cover varies between 0 to 50% with a mean cover between 5 and 10%. The tree cover in parklands with *Faidherbia albida* reaches more than 40 % (Badoua, 2007), with the highest percentage being with *Borassus aethiopium.* The high tree cover variations are related to famers` attitude (Larwanou and Saadou, 2011), tolarating or not the presence of trees in farms, the distribution of trees in natural vegetation, and crop production periods (Pullman, 1974), confirming the results of this study.

CONCLUSION

The conservation of tree species in farmers’ ` fields is an old practice in the Sahel but still gaining momentum because of loss of natural forests. This disappearance of natural forests is attributable in part to human pressure that requires an important land area for agricultural production. In Niger, parklands constitute more than 80% of arable lands under farmer management. The current number of observed species in the various villages showed how farmers are motivated in conserving and protecting trees in their farms. The difference of number of trees follows a rainfall gradient north-south. Farmer’s individual management, even though not covered by this study, could contribute in explaining this difference.

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